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ABSTRACT

This individualized learning module on multivibrators is one in a series of modules for a course in basic electricity and electronics. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instructional and curriculum development in a civilian setting. Three lessons are included in the module: (1) Bistable Multivibrator Operation (Flip-Flop), (2) Astable Multivibrator Operation (Free-Running), and (3) Monostable Multivibrator Operation (One-Shot). Each lesson follows a typical format including a lesson overview, a list of study resources, the lesson content, a programmed instruction section, and a lesson summary. (Progress checks are provided for each lesson in a separate document, CE 026 586.) (LRA)

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ED190898

CHIEF OF NAVAL EDUCATION AND TRAINING

1 APRIL 1977

Military Curricula for Vocational & Technical Education

BASIC ELECTRICITY AND ELECTRONICS.

MODULE 23. MULTIVIBRATORS.

STUDY BOOKLET.

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION
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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

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- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

OVERVIEW
BASIC ELECTRICITY AND ELECTRONICS
MODULE TWENTY THREE

Multivibrators

In this module you will learn about multivibrators. Multivibrators may be thought of as square wave generators. The output may be continuous square-waves, or pulses triggered by input waveforms.

This module has been separated into the following three lessons:

Lesson I	Bistable Multivibrator Operation (Flip-Flop)
Lesson II	Astable Multivibrator Operation (Free-Running)
Lesson III	Monostable Multivibrator Operation (One-Shot)

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY THREE

LESSON I

BISTABLE MULTIVIBRATOR OPERATION (FLIP-FLOP)

1 APRIL 1977

OVERVIEW
LESSON I

Bistable Multivibrator Operation (Flip-Flop)

In this lesson you will study and learn about the function of a basic flip-flop multivibrator. You will also learn the schematic representation of a flip-flop and its input and output waveforms.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

23.1.45.1 When the student completes this course, he will be able to TROUBLESHOOT multivibrator (flip-flop, free-running, one-shot) circuits, given a prefaulted training device, appropriate schematics (or technical manual), test equipment, and necessary tools. Remove and replace similar components on a practice circuit board. Faulty component identification must be 100% accurate. Component replacement must pass Learning Supervisor's inspection.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

23.1.45.1 IDENTIFY the schematic diagram of a flip-flop (bistable) multivibrator by selecting the correct schematic diagram from a set of four choices. 100% accuracy is required.

23.1.45.2 IDENTIFY the purpose of applying a triggering pulse to the toggle input of a bistable (flip-flop) multivibrator by selecting the correct statement from a set of four choices. 100% accuracy is required.

OVERVIEW

23.1.45.3 CONSTRUCT a basic flip-flop (bistable) multivibrator, given a schematic diagram or a parts layout template for a flip-flop multivibrator and a supply of parts. The constructed circuit must be operational as specified in the job program.

23.1.45.3.1 IDENTIFY the normal output waveform of a basic flip-flop multivibrator by selecting the illustration which resembles the normal output waveform of a flip-flop multivibrator for which the input signals and a flip-flop (with toggle) symbol are given. At least one input pulse will have no effect. 100% accuracy is required.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON I

Bistable Multivibrator Operation (Flip-Flop)

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following study resources:

Written Lesson presentation in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Job Program Twenty Three-I "Flip-Flop Multivibrator"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Three-I "Bistable Multivibrator"

Enrichment Material(s):

Basic Electronics, Vol. 2, NAVPERS 10087-C

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

SUMMARY
LESSON I

Bistable Multivibrator Operation (Flip-Flop)

Bistable multivibrators operate like two-position electronic switches. The bistable multivibrator circuit is frequently known as a flip-flop, because it has the ability to "flip" rapidly to one state or "flop" rapidly back to the other state. In either of its two states, the flip-flop is stable.

A flip-flop schematic is shown in Figure 1.

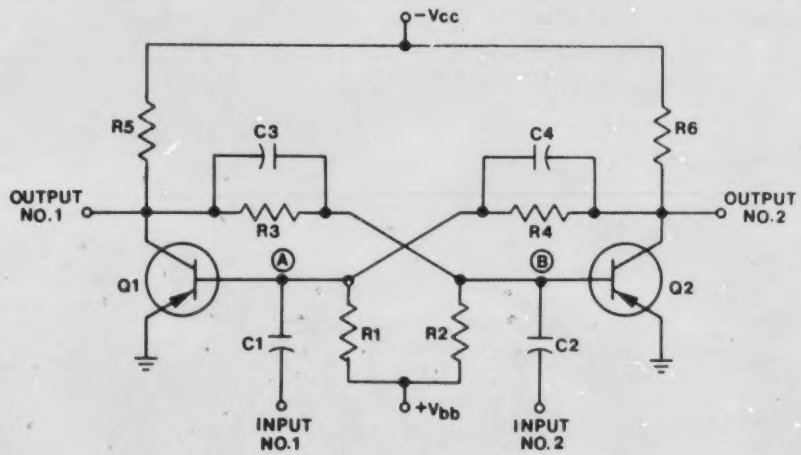


Figure 1

When the flip-flop is first energized, one transistor will go to cut-off and the other transistor will saturate. At no time can both transistors be saturated, and at no time can both transistors be cut-off. When one output measures a high voltage, the other output must be a low voltage.

The flip-flop can be made to change states by either applying a positive-going pulse to the saturated transistor (causing it to cut-off), or by applying a negative-going pulse to the cut-off transistor (causing it to saturate). Normally, a pulse is applied to the saturated transistor. This pulse is called a "trigger" pulse.

The block diagram symbol for a flip-flop circuit is shown in Figure 2.

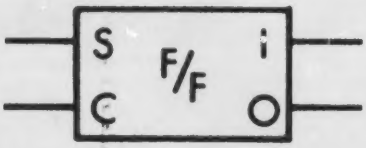


Figure 2

The two inputs are designed Set (S) and Clear (C). The two outputs are identified as "1" and "0". A trigger pulse on the Set input will cause the "1" output to go either positive or negative depending on the type of transistors used. At the same time the "0" output will equal zero volts. If the "1" output measures high voltage, the "0" output must measure a low voltage -- usually zero volts.

A clear state exists when the "1" output measures low voltage and the "0" output measures high voltage. The flip-flop will flop to the clear state only upon application of an enabling pulse to the clear (C) input.

There is a third input lead on some flip-flops. This lead is the "Toggle" (T) input as shown in Figure 3.

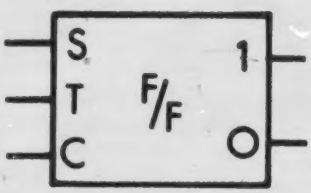


Figure 3

Every time a positive pulse is applied to the T input, the flip-flop will change states. This is accomplished with a diode steering network as shown in Figure 4. (Note that if NPN transistors were used the diodes would have to be reversed and the T signal would have to be negative.)

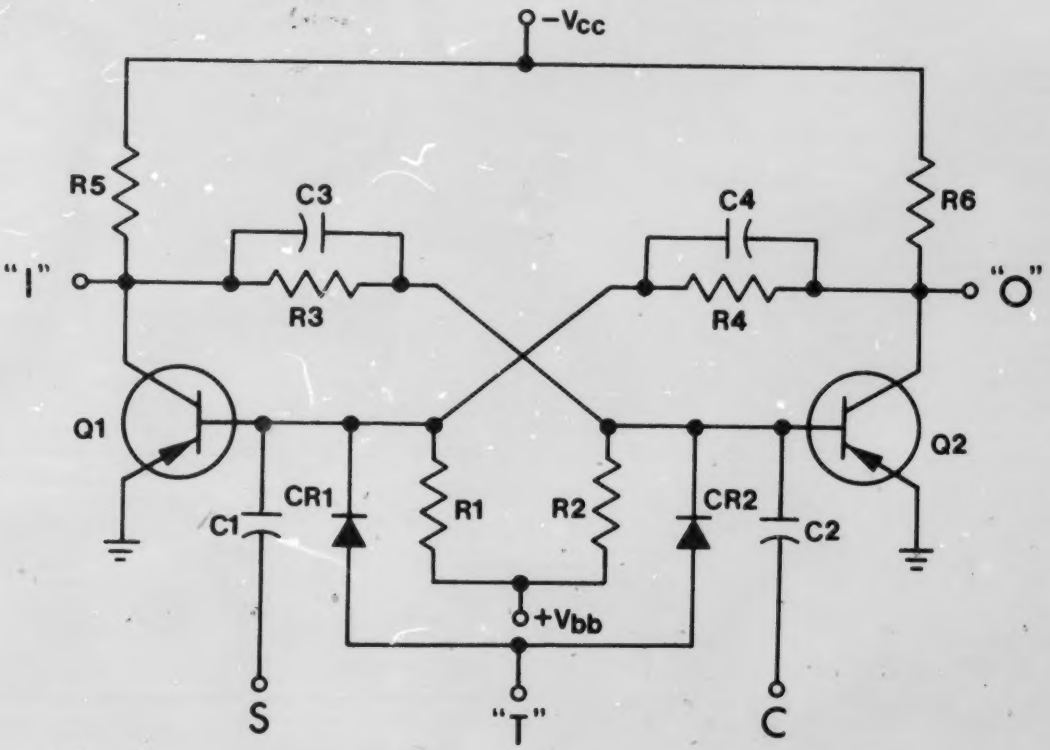


Figure 4

This steering network (CR1, CR2) will steer a positive input pulse to the saturated transistor -- causing it to cut-off.

For example, Figure 5 shows a sequence of input pulses and output voltage changes for a flip-flop originally in a clear state.

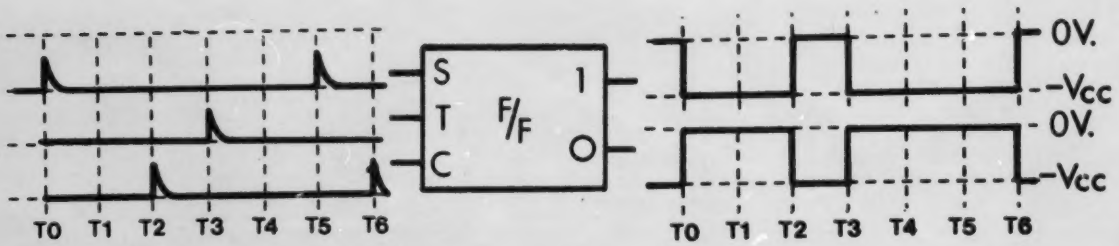


Figure 5

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON I

Bistable Multivibrator Operation (Flip-Flop)

TEST FRAMES ARE 9 AND 15. AS BEFORE, GO FIRST TO TEST FRAME 9 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. As a technician, you will encounter many applications of two-position switches. Bistable multivibrators function as if they were two-position switches: two-position electronic switches. Technicians generally know this circuit by another name: the flip-flop. Flip-flops can "flip" rapidly to one state or "flop" rapidly back to their original state. If you connected a voltmeter to the output of a flip-flop, you would measure either a particular high-voltage value or a particular low-voltage value. Unless something was wrong with the circuit, you would only measure one of those two particular values. Like any switch, the flip-flop would remain in that particular state until we change it by some external action. We sometimes say, therefore, that the flip-flop is stable in either of its two states.

The bistable multivibrator (flip-flop) has _____ stable states.

- -

two (2)

2. Study the schematic of a basic flip-flop shown in Figure 1. It's not as complicated as it first appears.

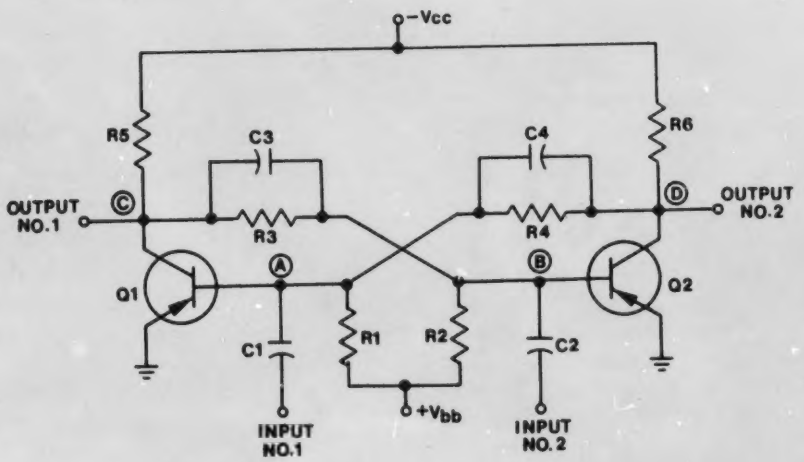


Figure 1

The flip-flop circuit is completely symmetrical. Notice that there are two inputs coupled to the bases of the transistors. The two outputs are coupled from the collectors of the transistors. Think of the flip-flop circuit as two common-emitter amplifier circuits -- where the output of one amplifier is connected to the input of the other amplifier and vice-versa.

Refer to Figure 1. Point D is the output of transistor Q2. Notice that point D is connected through R4 and C4 to point A. Point A is the input to transistor Q1.

Also, point C -- which is the output of Q1 -- is connected through R3 and C3 to the input of transistor Q2 (point B).

The output of one transistor will affect the input of the other transistor.

The voltage on the collector of Q2 will affect the voltage on the base of _____.

- -

Q1

3. When we apply power to the flip-flop, one of the transistors will go to saturation and the other transistor will go to cutoff. Why should the transistors react differently?

Actually, the transistors are matched as closely as possible. However, because of slight differences in conduction properties between any two transistors, the circuit will be slightly off-balance. This small difference causes one transistor to conduct more than the other. The transistor with the higher initial current flow will go into saturation. Remember that the output of one transistor affects the input of the other transistor. Because of the reduced voltage at the output of the saturated transistor, the other transistor will be forced into cutoff.

If one transistor in a flip-flop is saturated, the other transistor must be _____.

- -

cut-off

4. In order to explain why one transistor must be cut-off when the other transistor is saturated, let's assign typical values to the components and voltages in a flip-flop. Temporarily ignore the input capacitors and capacitors C3 and C4. The simplified typical circuit is shown in Figure 2.

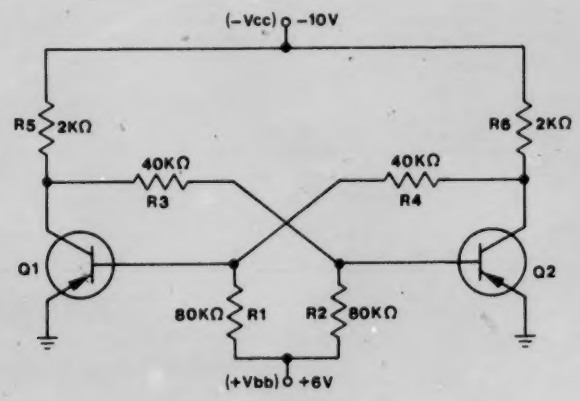


Figure 2

Two voltage divider networks extend from -10v (-Vcc) to +6v (+Vbb). One voltage divider consists of resistors R1, R4, and R6. The other voltage divider consists of resistors R2, R3, and R5.

Which voltage divider network supplies the bias potential to the base of Q1?

_____, _____, and _____.

- -

R1, R4, and R6.

5. Let's assume that in the initial state transistor Q1 is saturated and Q2 is cutoff. Remember that the voltage drop from the base to the emitter of a saturated transistor is essentially zero volts. Figure 3 shows the voltage drops on the voltage divider network connected to the base of Q1.

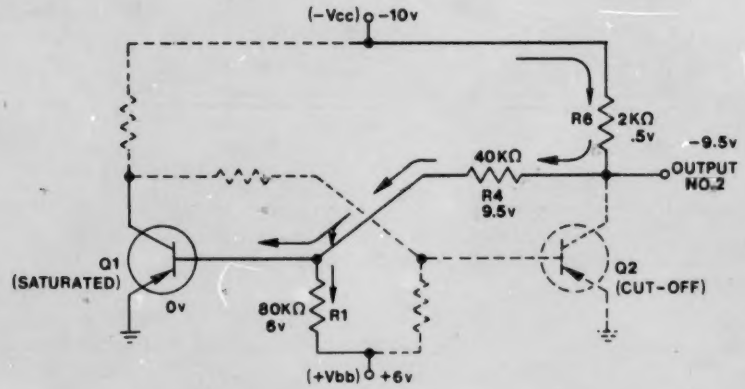


Figure 3

Since no current flows through Q2, very little voltage is dropped across R6 (approximately .5v). The voltage at output #2 in respect to ground would measure approximately -9.5V.

The voltage at the collector of the cutoff transistor (Q2) is approximately

a. -Vcc
b. 0v
c. +Vbb

- -

a. -Vcc (a high voltage output at output #2).

6. Refer to Figure 4 for the values on the other voltage divider network.

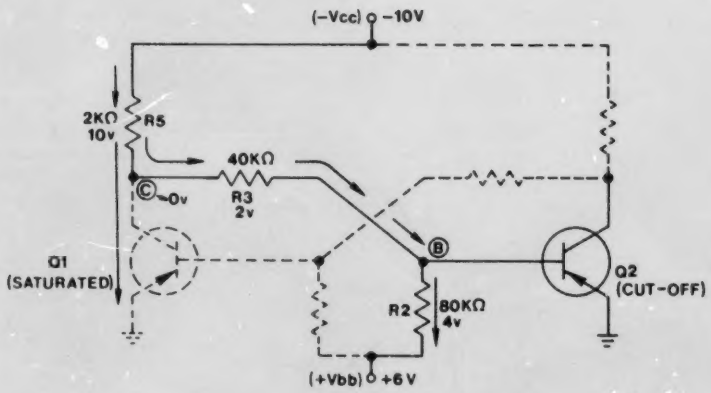


Figure 4

Since Q1 is saturated, there is a high current flow through R5. You would measure approximately zero volts (ground potential) at point C. Notice that the base of transistor Q2 is between 0v (at point C) and +6v (at +Vbb).

Therefore, the voltage at the base of transistor Q2 must be (positive/negative).

- -

positive (between 0v and +6v)

7. A positive voltage on the base of a PNP transistor will cause that transistor to become cutoff.

As you can see, the voltage on the base of one transistor is dependent on the voltage on the collector of the other transistor.

One transistor is saturated; the other must be cut off. The flip-flop is stable in this state.

Do not forget that the flip-flop is a "bi"-stable multivibrator, bi-two (2).

The flip-flop has _____ stable states.

- -

two (2)

8. So how do we change the state of the flip-flop?

Let's return the capacitors to the bistable multivibrator (Figure 5).

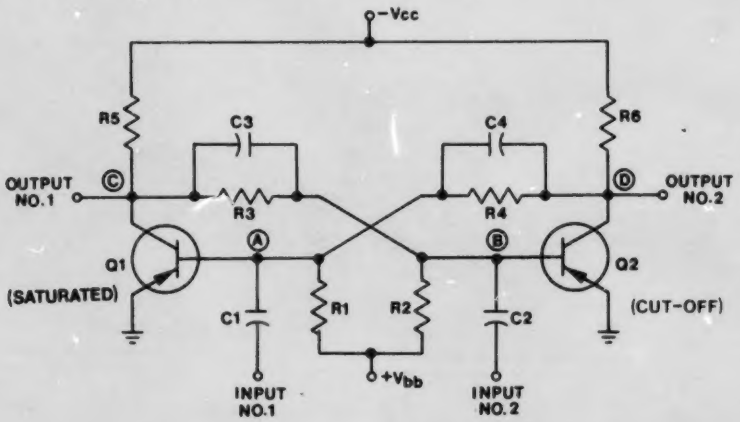


Figure 5

Capacitors C3 and C4 are used to transmit more rapidly any changes in voltage from the collector of one transistor to the base of the other transistor. C1 and C2 are input coupling capacitors.

As before, assume that transistor Q1 is saturated and transistor Q2 is cut-off. We now have a choice. We could apply a positive-going pulse to input #1 to cause Q1 to change from saturation to cut-off. Or we could achieve the same result by applying a negative-going pulse to input #2. Transistor Q2 would then change from cut-off to saturation. Normally, a pulse is applied to the saturated transistor -- causing it to cut-off. An input pulse which is of the correct polarity to change the state of the flip-flop is called a "trigger" pulse.

If Q2 in Figure 5 is saturated, the preferred method for changing the state of the circuit is to apply a (positive/negative) pulse to (Q1/Q2).

- -

positive, Q2

9. TEST FRAME

In Figure 6, we have applied a positive-going pulse to input #1 at time T1.

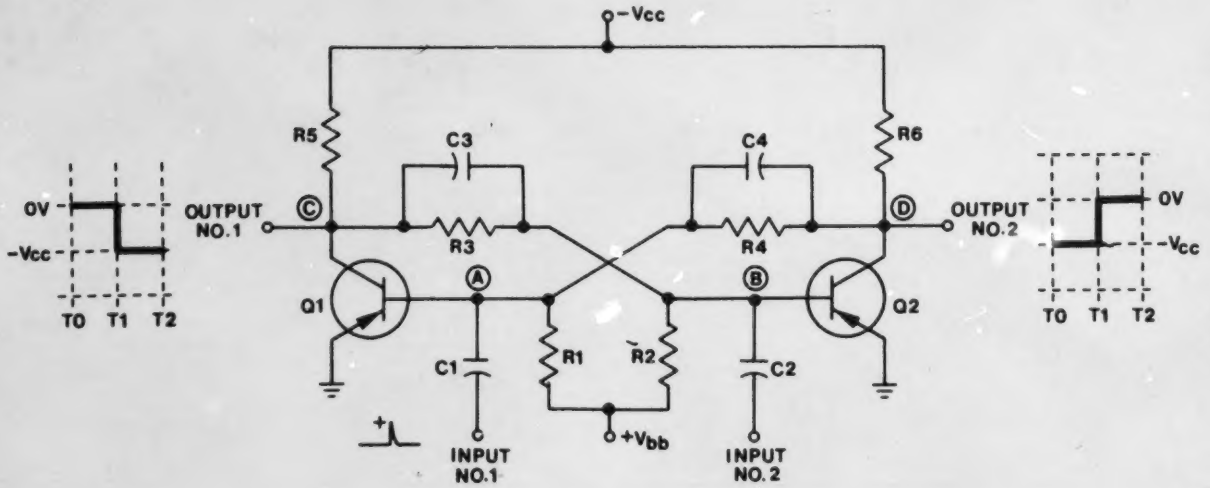


Figure 6

Now: Q1 is _____ _____; Q2 is _____.

- -

THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.

cut-off, saturated (in that order)

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 15. OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 9 AGAIN.

10. Apply a second positive-going pulse to input #1. There will be no effect. Why? Because Q1 is already cut-off.

Now apply a positive pulse to input #2; Q1 will go back into saturation and Q2 will again be cut-off; see Figure 7.

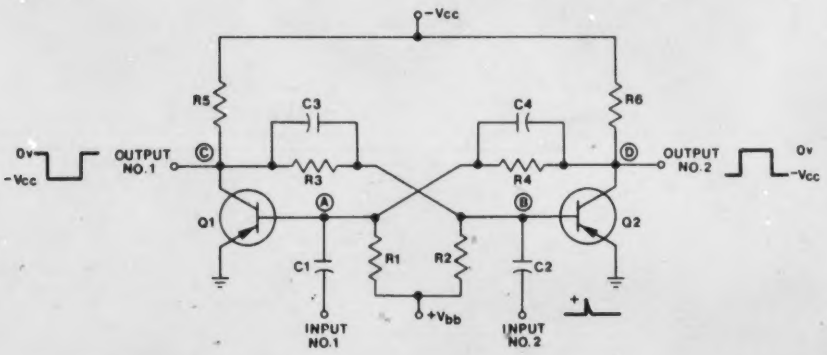


Figure 7

What would happen to the outputs now if a second positive pulse were applied to input #2?

- -

Nothing! Since Q2 is already cut-off, a positive pulse would have no effect.

11. A special vocabulary has been developed to simplify writing and talking about flip-flops and their inputs and outputs. For example, the inputs are often referred to as the "SET" (S) and "CLEAR" (C) inputs rather than INPUT No. 1 and INPUT No. 2. The output controlled directly by the SET input is called a "1" (one) output, and the output associated with the clear input is the "0" (zero) output. The schematic with these labels looks like Figure 8.

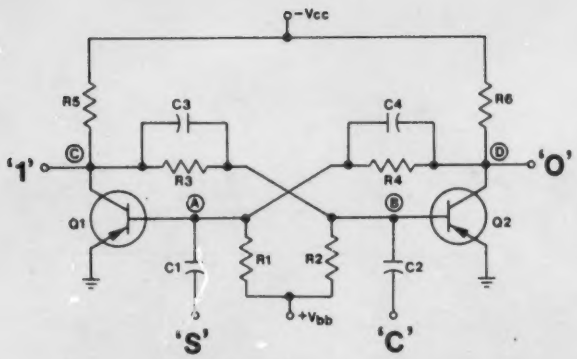


Figure 8

What output in Figure 8 will be nearly Vcc immediately after a positive pulse has been applied to the SET input?

- -

The 1 output will measure approximately Vcc.

12. A simpler way to show a flip-flop, once you understand how it functions, is to draw a block diagram to represent the circuit. A special kind of block has been adopted as a standard symbol for the flip-flop, and it looks like this:

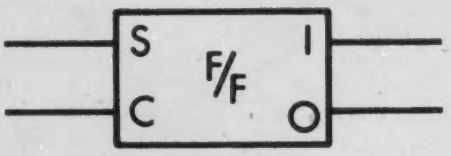


Figure 9

The two inputs are represented by the lines on the left and the outputs by the lines on the right.

INPUTS to flip-flop are S (SET) and C (CLEAR)
OUTPUTS from flip-flop are "1" and "0"

A trigger pulse applied to the Set input causes the "1" output to go positive or negative, depending on the type of transistor. At the same time, the "0" output will equal zero volts. This condition is called the Set State. In the set state the "1" output is a high voltage (or just "high") and the "0" output is zero volts.

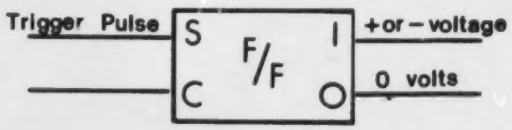


Figure 10

If another trigger pulse is applied to the Clear input, this produces a positive or negative voltage (high) out of the "0" output. The "1" output goes to zero volts (low). This condition is called the Clear State.

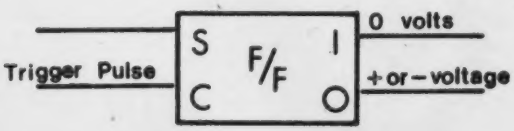


Figure 11

To determine what state the flip-flop is in, you can measure either the "1" or the "0" output.

Using a voltmeter you measure the "1" output and find -6v. The flip-flop is in the (clear/set) state.

- -

set

13. Some flip-flops use a third input lead. This third input lead is called a "Toggle" (T) input. Every time we apply a pulse to the T input, the flip-flop will change states. Refer to Figure 12.

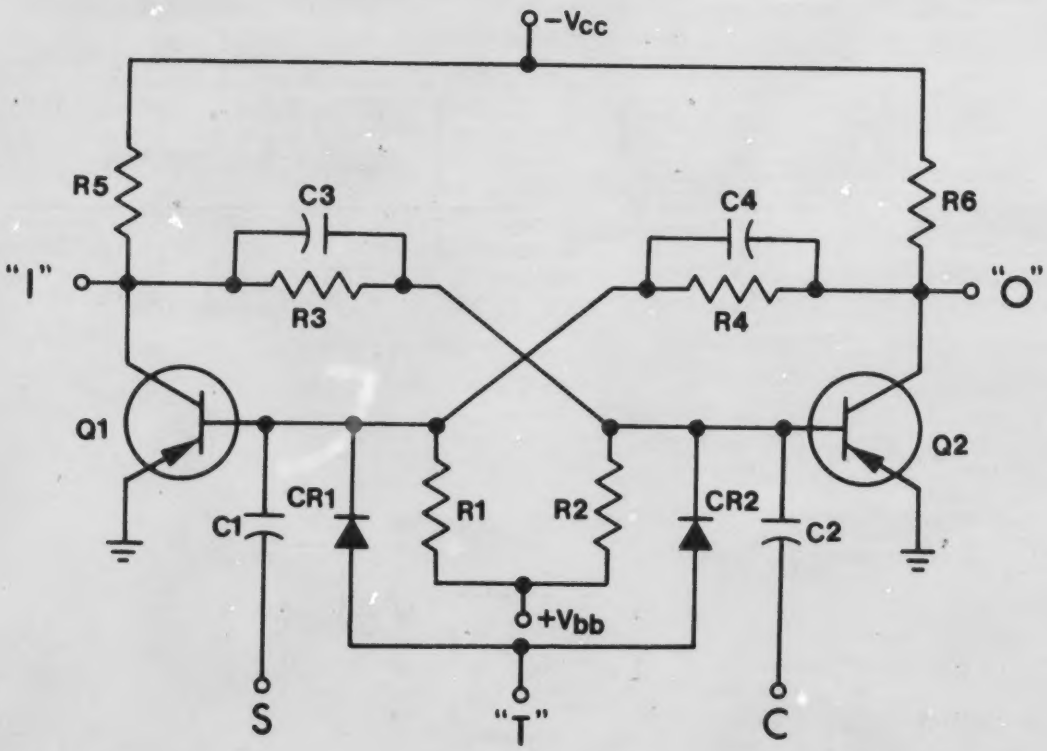


Figure 12

The two diodes (CR1, CR2) form a "steering network". This steering network will steer a positive input pulse to the saturated transistor -- causing it to cut-off. Negative pulses are blocked by the diodes. (Note that if NPN transistors were used the diodes would have to be reversed and the T signal would have to be negative.)

For example, let's say that Q1 is saturated and Q2 is cut-off. We apply a positive pulse at T. The pulse will be passed to both transistors. The positive pulse will not affect Q2 since it is already cut-off. Q1, however, will cut-off which will cause Q2 to become saturated. The transistors have reversed states.

What will happen if we apply another positive pulse at T?

- -

The transistors will again change states -- Q1 will be saturated and Q2 will be cut-off (or words to that effect).

14. Figure 13 represents the block diagram of Figure 12. The input is on Toggle (T) and the output is as shown.

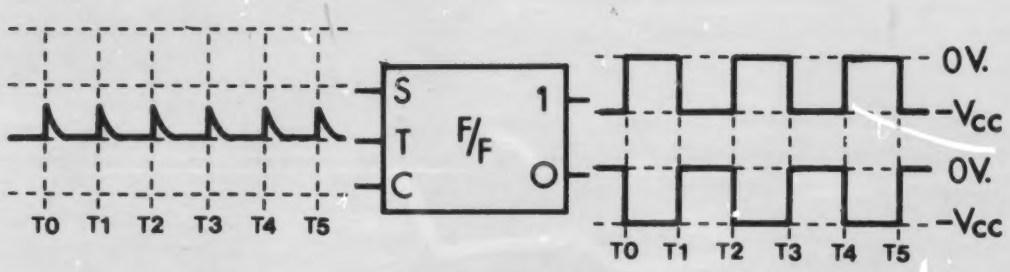


Figure 13

Draw the waveform that would appear at the "1" output with a T input as shown in Figure 14 (assume "0" volts out at T_0).

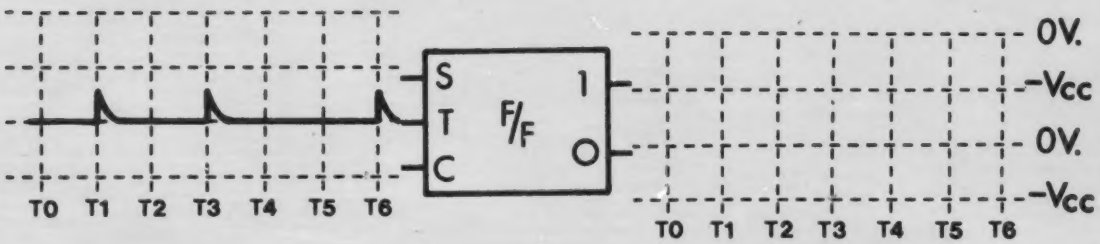
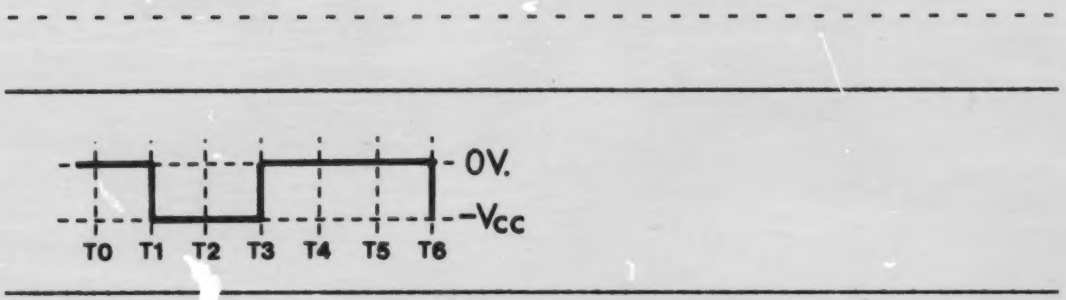


Figure 14



15. TEST FRAME

Draw the correct "1" output waveform for the flip-flop in Figure 15 with the Set (S), Clear (C), and Toggle (T) inputs shown. (Assume flip-flop originally in the Clear state.)

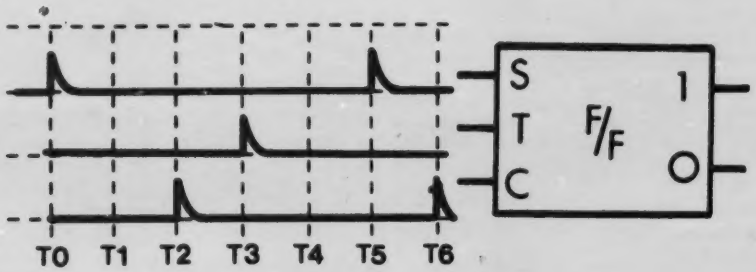
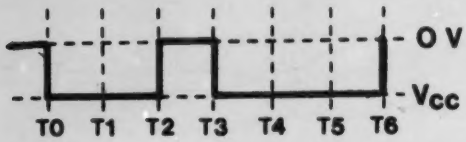


Figure 15

- -

THIS IS A TEST FRAME. COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.



IF YOUR ANSWER MATCHES THE CORRECT ANSWER YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON I MODULE TWENTY THREE. OTHERWISE GO BACK TO FRAME 10 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 15 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON I

Bistable Multivibrator Operation (Flip-Flop)

You are familiar with two-position switches. Bistable multivibrators operate like two-position electronic switches. Technicians know this circuit by two other names: the Eccles-Jordan circuit and -- most commonly -- the flip-flop. Flip-flops can "flip" rapidly to one state or "flop" rapidly back to their original state. If you connected a voltmeter to the output of a flip-flop, you would measure either a particular high-voltage value or a particular low-voltage value. No matter which value you measured, the flip-flop would be stable.

Stable?

"Stable" means that the flip-flop will remain in a particular condition indefinitely. It will not change states unless we apply the proper type of "trigger" pulse.

You will find flip-flops used in switching-circuit applications (computer logic operations) like counters, shift registers, clock pulses, and memory circuits. You will also find them used for relay-control functions, and for a variety of similar applications in radar and communications systems.

Notice that the basic flip-flop illustrated in Figure 1 has two inputs and two outputs.

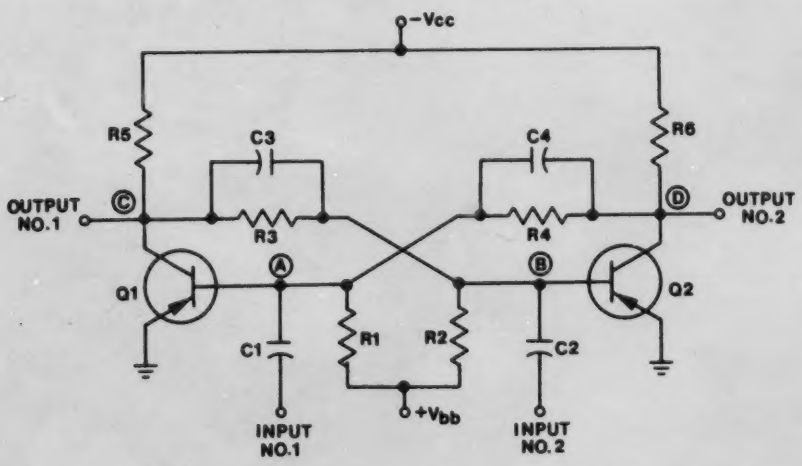


Figure 1

The circuit probably looks complicated to you if you are seeing it for the first time. Actually, because it is symmetrical, we can analyze it with little difficulty. The inputs are coupled to the bases of the transistors and the outputs are coupled from the collectors of the transistors. Think of the flip-flop as two common-emitter amplifier circuits -- where the output of one amplifier is connected to the input of the other amplifier and vice-versa. Refer to Figure 1. Point D is the output of transistor Q2. Notice that point D is connected through R4 and C4 to point A. Point A is the input to transistor Q1.

By the same token, point C -- which is the output of Q1 -- is connected through R3 and C3 to the input of transistor Q2 (point B). The output of one transistor will affect the input of the other transistor.

When we apply power to the flip-flop, one of the transistors will saturate and the other transistor will cut off. But because of slight differences in conduction properties between any two transistors, one transistor will conduct slightly more than the other transistor. This slight difference in conduction properties is enough to throw the flip-flop off balance. One of the transistors will continue to increase its current flow until it reaches saturation. When this transistor reaches saturation, its collector voltage is very low in respect to ground. Since the voltage on the collector of one transistor affects the base voltage of the other transistor, the other transistor will be forced into cut-off.

The transistors operate almost as if they were two mechanically interconnected switches. When one switch opens, the other switch is forced to close, and vice-versa (Figure 2).

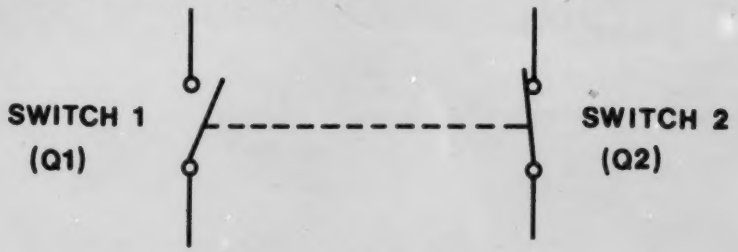


Figure 2

At no time can both switches (transistors) be in the same state.

If one transistor in a flip-flop is saturated, the other transistor must be _____.

- -

cut-off

Let's take a close look at the flip-flop circuit to see how it maintains its stable conditions. We show typical values for the resistors and applied voltages in Figure 3. To keep the circuit simple, we have also removed the capacitors.

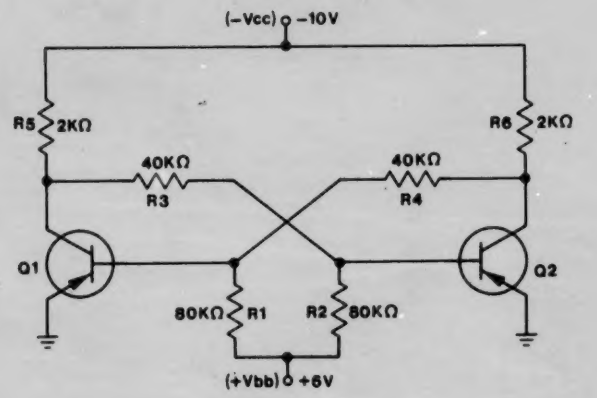


Figure 3

Two voltage divider networks extend from -10v (-Vcc) to +6v (+Vbb). One voltage divider consists of resistors R1, R4, and R6 and supplies the bias voltage to the base of Q1. The other voltage divider consists of R2, R3, and R5 and supplies the bias voltage to the base of Q2.

Let's assume that initially Q1 is saturated and Q2 is cut-off. Remember that the voltage drop from the base to the emitter of a saturated transistor is essentially zero volts. Figure 4 shows the voltage drops on the voltage divider network connected to the base of Q1.

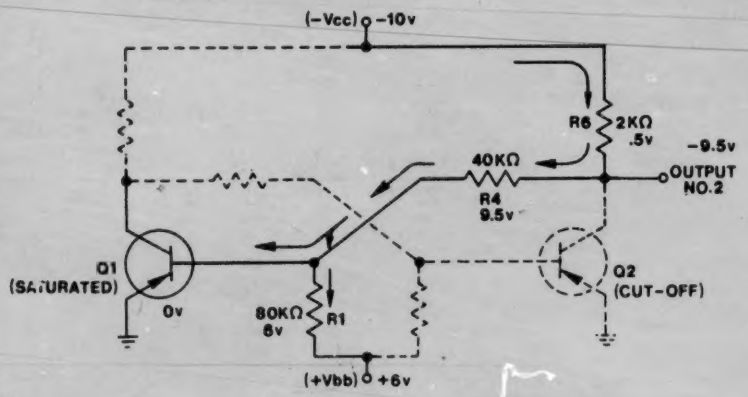


Figure 4

Since no current flows through Q2, very little voltage is dropped across R6 (approximately 0.5v). The voltage at output #2 would measure -9.5v in respect to ground (approximately -Vcc).

This voltage (-9.5v) is considered to be a high voltage output at output #2. (Output #2 is said to be high.)

Refer to Figure 5 for the values on the other voltage divider network.

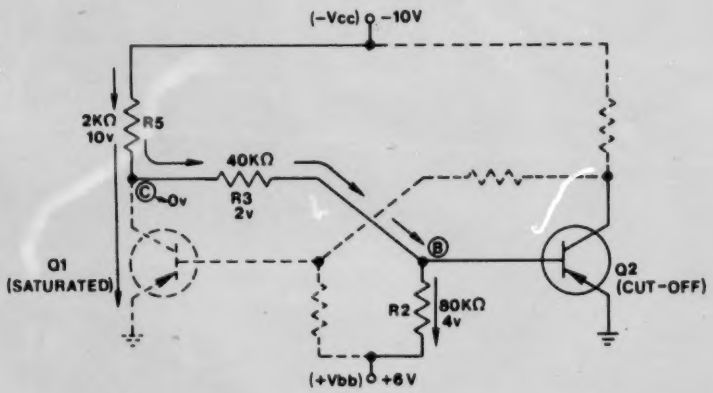


Figure 5

Since Q1 is saturated, a large current flows through R5. You would measure approximately zero volts (ground potential) at point C. Notice that point B is located between point C (at 0v) and +Vbb (at +6v). You would measure a positive voltage (between 0v and +6v) at the base of Q2 (point B). A positive voltage on the base of a PNP transistor will cause that transistor to become cut-off.

One transistor is saturated; the other must be cut-off. The flip-flop is stable in this state.

Do not forget that the flip-flop is a "bi" -stable multivibrator: bi meaning two (2); the flip-flop has two stable states.

So how do we change the state of the flip-flop?

Let's return the capacitors to the bistable multivibrator (Figure 6).

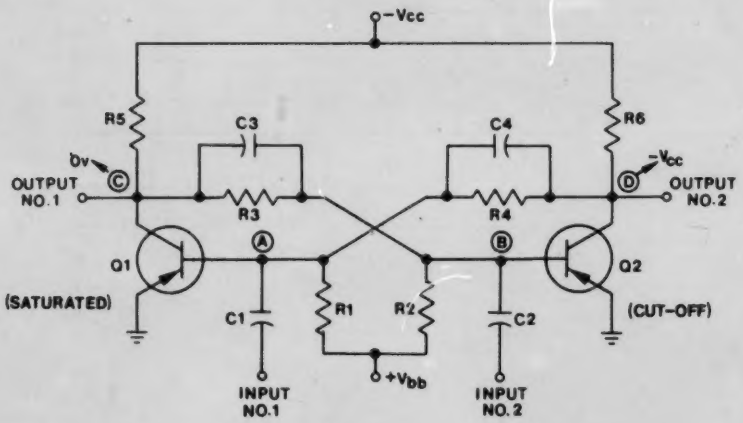


Figure 6

Capacitors C3 and C4 transmit more rapidly any changes in voltage from the collector of one transistor to the base of the other transistor. Capacitors C1 and C2 are input coupling capacitors.

As before, assume that transistor Q1 is saturated and transistor Q2 is cut-off. We now have a choice. We could apply a positive-going pulse to input #1 to cause Q1 to change from saturation to cut-off. Or we could achieve the same result by applying a negative-going pulse to input #2. Transistor Q2 would then change from cut-off to saturation. Normally, a pulse is applied to the saturated transistor -- causing it to cut-off. An input pulse which is of the correct polarity to change the state of the flip-flop is called a trigger pulse.

In Figure 7, we have applied a positive-going pulse to input #1. The flip-flop has changed states. Now: Q1 is cut-off; Q2 is saturated. This input pulse is a trigger pulse.

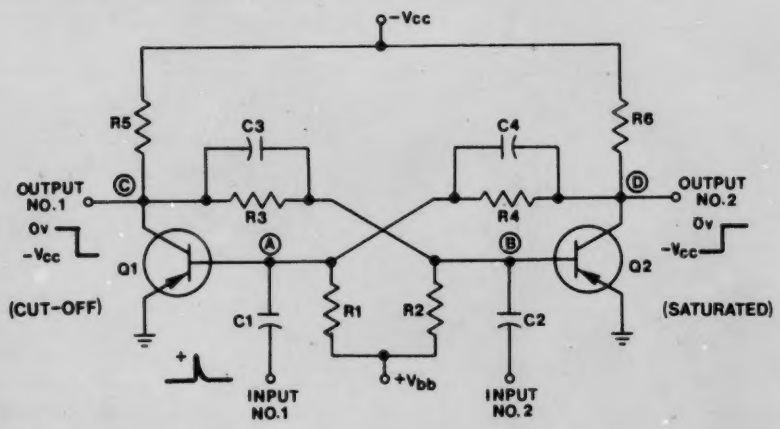


Figure 7

Apply a second positive-going pulse to input #1. The effect is: no effect!! Why? Because Q1 is already cut-off, a positive pulse on its base will have no effect.

But if you now applied a positive-going pulse to input #2, the flip-flop would change back to its original state (Figure 8).

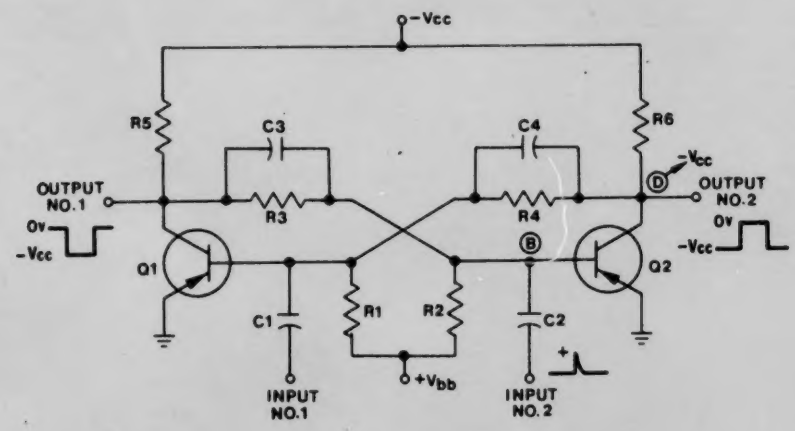


Figure 8

So far, our basic flip-flop used only PNP transistors. We could have just as easily used NPN transistors. Functional operation doesn't change, only the polarities required for conduction and cut-off change.

As a technician, you may see either type NPN or PNP. All you are really concerned with is whether or not it operates properly. To avoid possible confusion with voltage polarities, we sometimes use a symbolic block diagram, see Figure 9.

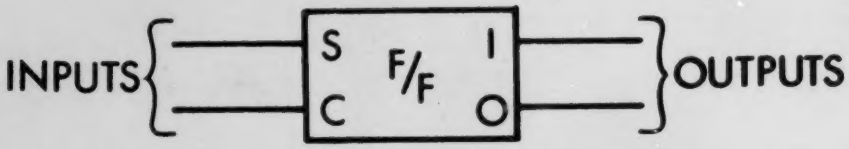


Figure 9

INPUTS to flip-flop are S(SET) and C(CLEAR)
OUTPUTS from flip-flop are "1" and "0"

A trigger pulse applied to the Set input causes the "1" output to go positive or negative, depending on the type of transistor. At the same time, the "0" output will equal zero volts. This condition is called the Set state (Figure 10).

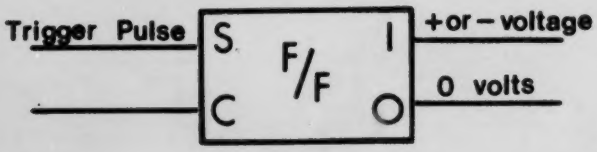


Figure 10

If another trigger pulse is applied to the Clear input, this produces a positive or negative voltage out of the "0" output. The "1" output goes to zero volts. This condition is called the Clear State; see Figure 11.

To determine what state the flip-flop is in, you can measure either the "1" or the "0" output. Measuring 0 volts at the "1" output tells us the flip-flop is in the Clear state. If, on the other hand, we had measured the "0" output, the positive or negative voltage would also have told us we were in the Clear state. Either way, we'd only need to take one reading.

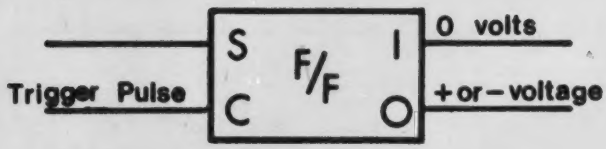
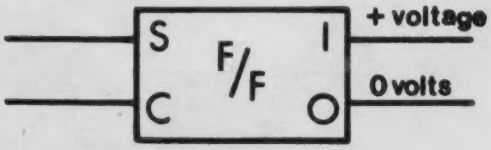


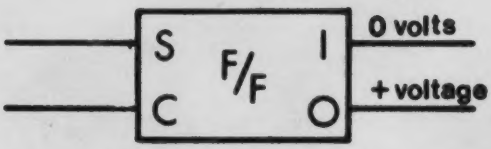
Figure 11

In the below examples, indicate the state (Set or Clear) of the flip-flops.

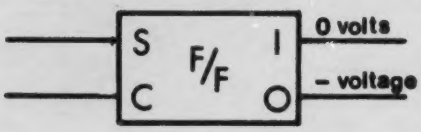
1. _____



2. _____



3. _____



4. _____

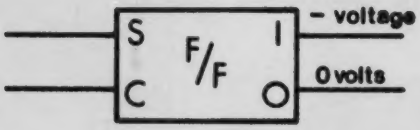


Figure 12

- - - -

1.	Set
2.	Clear
3.	Clear
4.	Set

Look now at Figure 13. The flip-flop is originally in the set state.

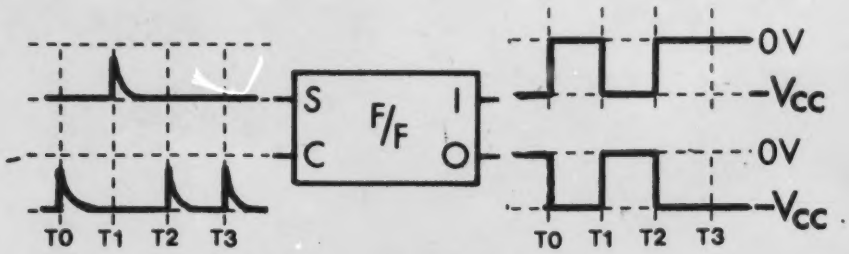


Figure 13

In Figure 13, compare the changes in output voltage at each point in time (T0, T1, etc.) with the input pulses. Careful study of this figure should establish in your mind exactly how a flip-flop works.

Some flip-flops use a third input lead. This third input lead is called a "Toggle" (T) input. Every time we apply a pulse to the "T" input, the flip-flop will change states. Refer to Figure 14.

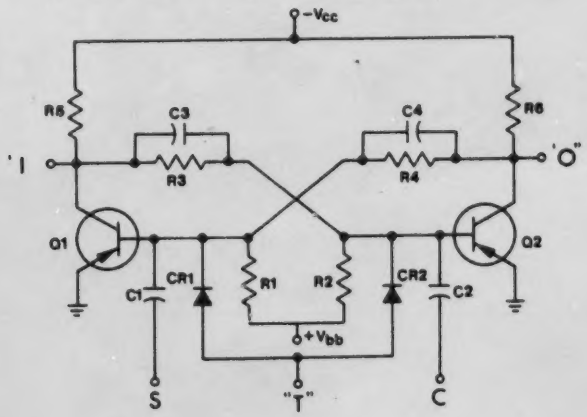


Figure 14

The two diodes (CR1, CR2) form a "steering network". This steering network will steer a positive input pulse to the saturated transistor -- causing it to cut-off. Negative pulses are blocked by the diodes. (Note that if NPN transistors were used the diodes would have to be reversed and the T signal would have to be negative.)

For example, let's say that Q1 is saturated and Q2 is cut-off. We apply a positive pulse at T. The pulse will be passed to both transistors. The positive pulse will not affect Q2 since it is already cut-off. Q1, however, will become cut-off which will cause Q2 to become saturated. The transistors have reversed states.

On the block diagram below, which represents the Multivibrator of Figure 14, the Toggle (T) input is as shown in Figure 15.

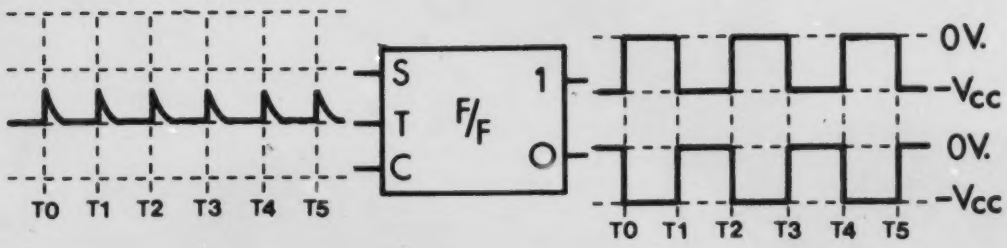


Figure 15

Now let's see what happens when triggers are applied to all three inputs of the multivibrator shown in Figure 14. In Figure 16 assume the flip-flop is in the clear state ("1" output is 0.0 volts, "0" output is high) prior to T0.

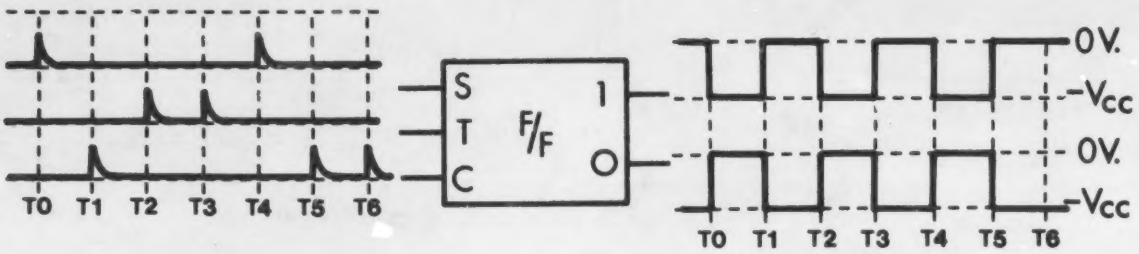
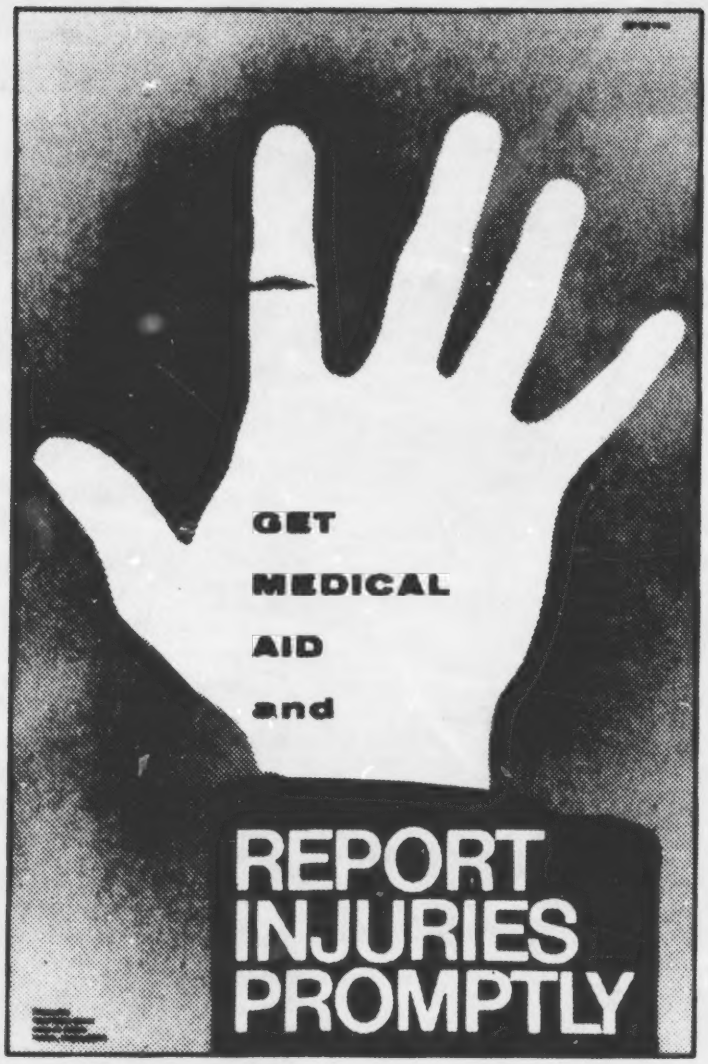


Figure 16

At T0 a trigger is applied to the set input and the multivibrator changes states. Next, the clear input is triggered and the flip-flop returns to the clear state at T1. A toggle pulse at T2 causes the multivibrator to change state, so it is once again set. Another toggle changes the flip-flop to the clear state at T3 (notice that toggle triggers flip the multivibrator regardless of its state). Now a set input trigger at T4 sets the flip-flop. The clear input pulse at T5 clears the circuit, and the clear input at T6 has no effect on the flip-flop, for it is already in the clear state.

To summarize, a set input will set the flip-flop if it is in the clear state, otherwise, it will not do anything; a trigger at the clear input can only clear the circuit if it is set; and a trigger applied to the toggle will cause the bistable multivibrator to change states regardless of what state it is in.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.


GET
MEDICAL
AID
and
REPORT
INJURIES
PROMPTLY

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY THREE

LESSON 11

ASTABLE MULTIVIBRATOR OPERATION (FREE-RUNNING)

1 APRIL 1977

OVERVIEW
LESSON II

Astable Multivibrator Operation (Free-Running)

In this lesson, you will study and learn about the function of a basic astable multivibrator; its schematic and its output waveform.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

23.2.45 When the student completes this course, he will be able to TROUBLESHOOT multivibrator (flip-flop, free-running, one-shot) circuits, given a prefaulted training device, appropriate schematics (or technical manual), test equipment, and necessary tools. Remove and replace similar components on a practice circuit board. Faulty component identification must be 100% accurate. Component replacement must pass Learning Supervisor's inspection.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

23.2.45.4 IDENTIFY the schematic diagram of a free-running (astable) multivibrator by selecting the correct schematic from a set of four choices. 100% accuracy is required.

23.2.45.5 IDENTIFY the correct output waveform of a basic free-running (astable) multivibrator by selecting the correct waveform description or illustration from a set of four choices. 100% accuracy is required.

23.2.45.6 CONSTRUCT a basic free-running (astable) multivibrator, given a schematic diagram or a parts layout template for a free-running or astable multivibrator and a supply of parts. The constructed circuit must be operational as specified in the job program.

OVERVIEW

23.2.45.6.1 OBSERVE, RECORD, and INTERPRET normal and abnormal output waveforms of a free-running (astable) multivibrator, given the necessary schematics, tools, job program, oscilloscope, and components or circuit boards. All measurements must fall within tolerances stated in the job program.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON III

Monostable Multivibrator Operation (One-Shot)

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following study resources:

Written Lesson presentation in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Job Program Twenty Three-III-1 "Monostable Multivibrator"
Job Program Twenty Three-III-2 "Multivibrator Systems"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Three-III "Monostable Multivibrator Operation"

Enrichment Material(s):

Basic Electronics, Vol. 2, NAVPERS 10087-C

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

SUMMARY
LESSON II

Astable Multivibrator Operation (Free-running)

An astable multivibrator is also known as a free-running multivibrator. It is called free-running because it freely alternates between two different output voltage levels. The output is a square-wave used for timing and gating purposes in electronic equipment.

The schematic of the astable multivibrator is shown in Figure 1.

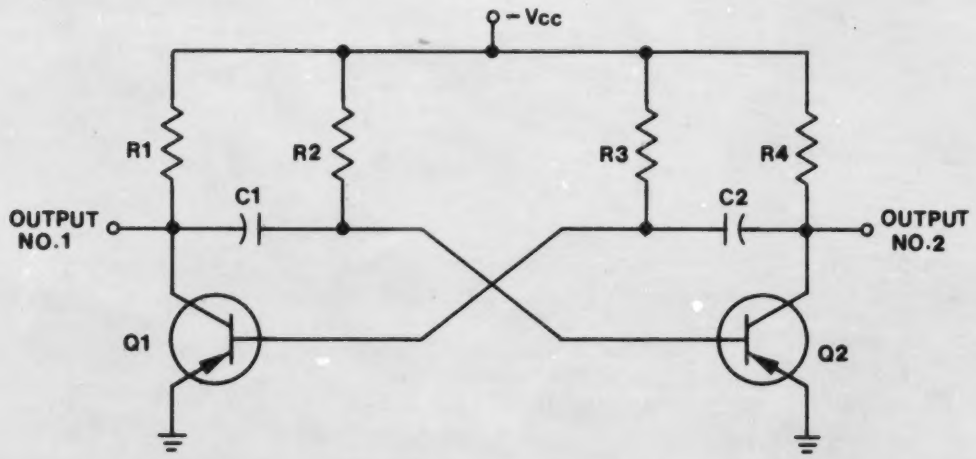


Figure 1

Like the flip-flop, the astable multivibrator has two outputs. But the astable multivibrator has no inputs. It is a type of oscillator since it generates a continuous output signal (a square wave) with no input signal.

When the circuit is energized, one of the transistors will cut-off. Therefore, one output will be a relatively high voltage (approximately -Vcc) when the other output is a low voltage (approximately 0 V).

Figure 2 illustrates an astable multivibrator with Q1 saturated and Q2 cut-off.

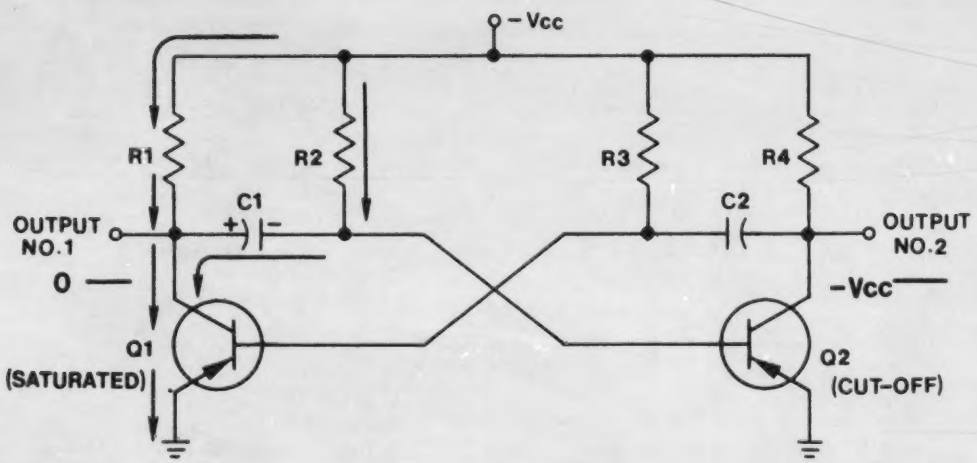


Figure 2

The circuit will remain in this state for a definite period of time. This period of time is determined by the time constant R2 X C1. Capacitor C1 is connected to the base of transistor Q2 (which is now cut-off). As the right side of C1 charges (becomes more negative), the base of Q2 is also becoming more negative. When the base of Q2 becomes sufficiently negative to cause Q2 to conduct, Q2 will rapidly saturate. The resulting rise in voltage at output #2 (from approximately -Vcc to approximately 0v) is transmitted through C2 to the base of transistor Q1. Transistor Q1 then goes into a state of cut-off.

The conditions of the two transistors have now been reversed. Figure 3 illustrates Q1 cut-off and Q2 saturated.

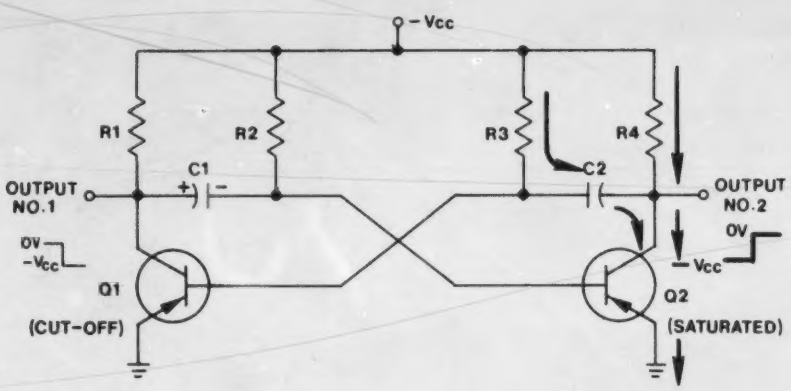


Figure 3

Now the left side of C2 will become more and more negative, depending on the time constant R3 X C2.

The base of Q1, consequently, becomes more and more negative. After a definite period of time, Q1 will again saturate and Q2 will cut-off.

The output voltage from transistor Q2 is illustrated in Figure 4.

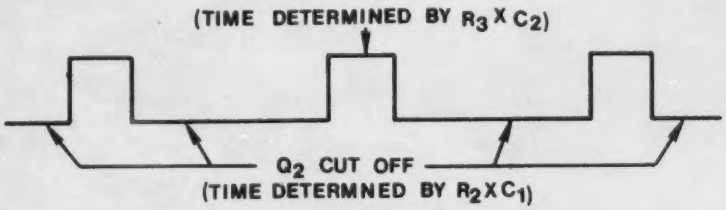


Figure 4

The output voltage (from either output) continually alternates from approximately 0 V to approximately -Vcc -- remaining in each state for a definite period of time. This output is used for various timing purposes -- operating like an electronic clock.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON II

Astable Multivibrator Operation (Free-running)

THE TEST FRAME IS 7. GO FIRST TO TEST FRAME 7 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. The astable multivibrator is a type of oscillator. A square-wave oscillator. Once it is energized, it will develop a continuous square wave at either of its two outputs (Figure 1).

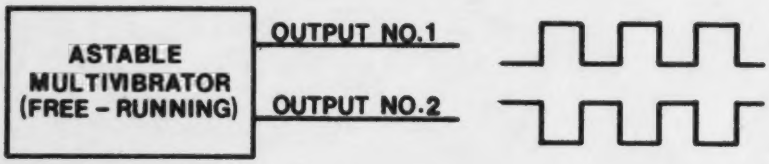


Figure 1

Recall that the bistable multivibrator (flip-flop) required a trigger input pulse to change states. The astable multivibrator doesn't even have any inputs. It will change states automatically, staying in each state for a definite period of time. You will find that this circuit is also called the free-running multivibrator; once it gets started, it will freely change from a high voltage to a low voltage level and back and forth with no trigger input pulses.

The output of a free-running multivibrator is a _____ wave.

- -

square

2. Does the schematic in Figure 2 look familiar? It is similar to the flip-flop schematic.

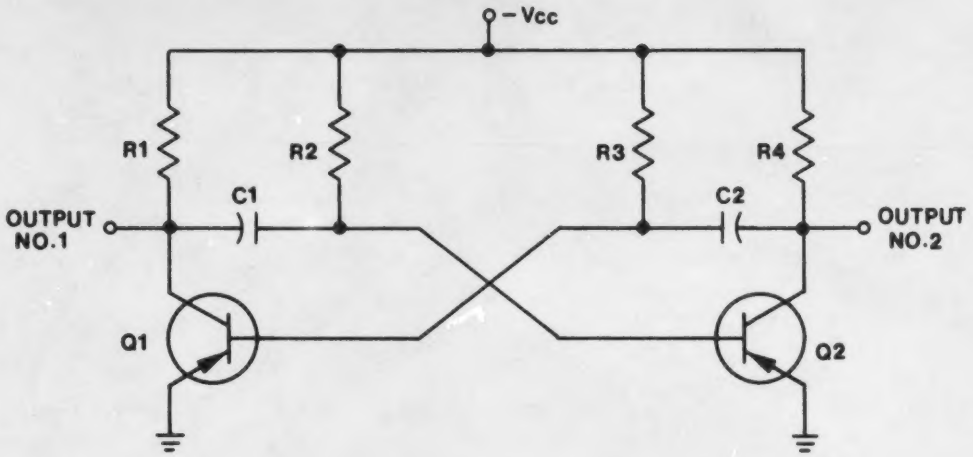


Figure 2

The biggest difference is that the astable multivibrator has no inputs, yet it has two outputs. Like the flip-flop, one of the transistors will saturate and the other transistor will cut off when we energize the circuits. So if you measured a high voltage at one output, you would measure a low voltage at the other output.

In Figure 2, if Q1 is saturated, Q2 must be _____.

- -

cut-off

3. The flip-flop and the astable multivibrator look similar. Why should they operate differently? Why does the astable multivibrator "oscillate", whereas the flip-flop doesn't? Let's explore the reasons.

Refer to Figure 3. Say that transistor Q1 is conducting, but transistor Q2 is cut-off.

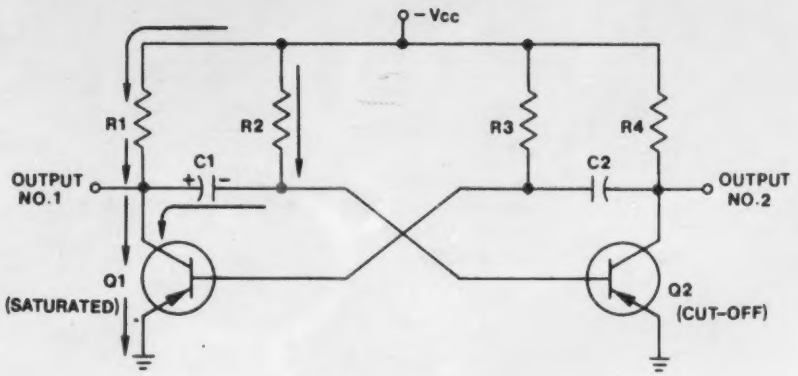


Figure 3

Essentially ALL the current in the circuit flows through Q1. Q1 offers almost no resistance to current.

Notice that capacitor C1 is charging. Since Q1 has almost no resistance in a saturated state, the rate of charge of C1 is dependent on which time constant?

a. R1 X C1
b. R2 X C1
c. R3 X C1

- -

b. R2 X C1

4. Why do you suppose we are concerned with the charging of C1? Well, notice that C1 is connected to the base of transistor Q2. Q2 is cut-off. But as its base becomes more negative because of the charging of C1, Q2 will start to conduct and will rapidly saturate. (Remember that the conduction of a transistor is controlled by the voltage on its base.)

Q2 is now conducting. What effect do you think this will have on Q1? Refer to Figure 4.

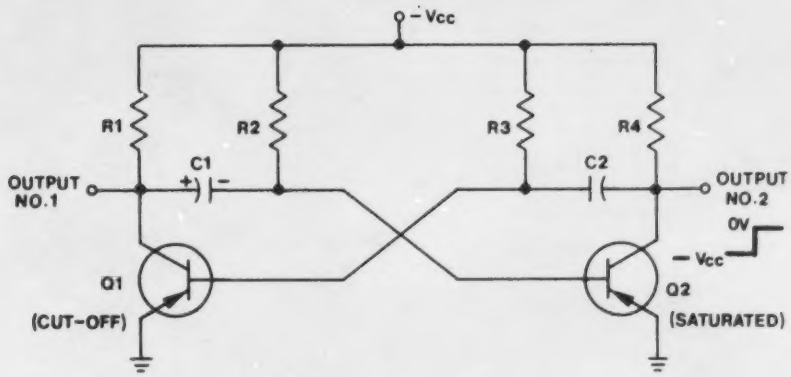


Figure 4

When Q2 saturates, output #2 changes from approximately -Vcc to approximately 0v. This rise in voltage will be coupled through C2 to the base of Q1, causing Q1 to go into cutoff.

When Q2 saturates, Q1 will become _____.

- -

cut-off

5. Essentially all the current in the system now flows through Q2. See Figure 5.

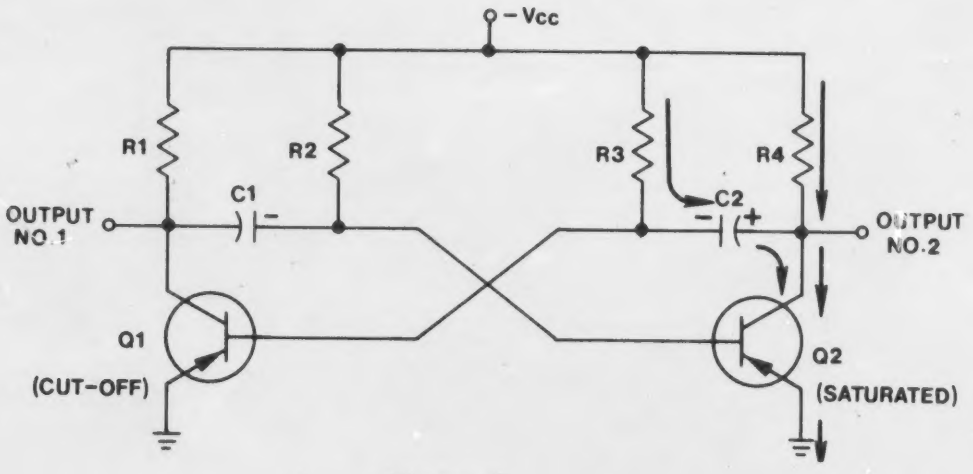


Figure 5

We now have the mirror image of what we had a moment ago. The left side of capacitor C2 will now become more negative at a rate determined by the time constant R3 X C2. As the left side of C2 becomes more negative, the base of Q1 will also become more negative. When the base of Q1 becomes negative enough to allow Q1 to conduct, Q1 will again go into saturation and Q2 will again go to cut-off.

The length of time that transistor Q1 remains cut-off is determined by the charging rate of capacitor _____.

- -

C2

6. Let's analyze the output voltage from transistor Q2. Refer to Figure 6.

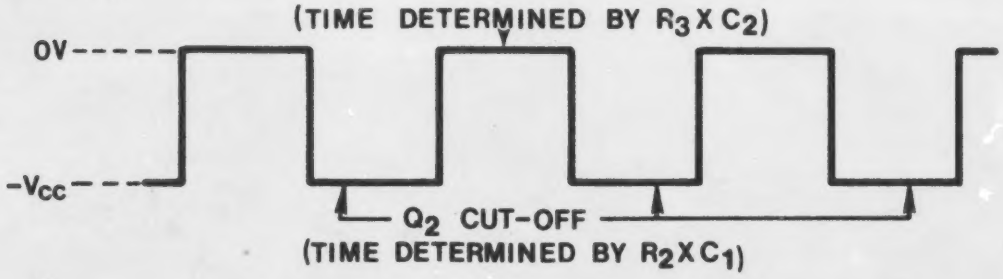


Figure 6

The output voltage continually alternates from approximately 0 V to approximately -Vcc -- remaining in each state for a definite period of time. The time may range from a microsecond to as much as a second or two. In many applications, the time period of high voltage and the time period of low voltage will be equal.

Some applications, however, require different high and low voltage times.

Suppose you need an astable multivibrator that produces an output with different pulse widths. Maybe something like Figure 7.

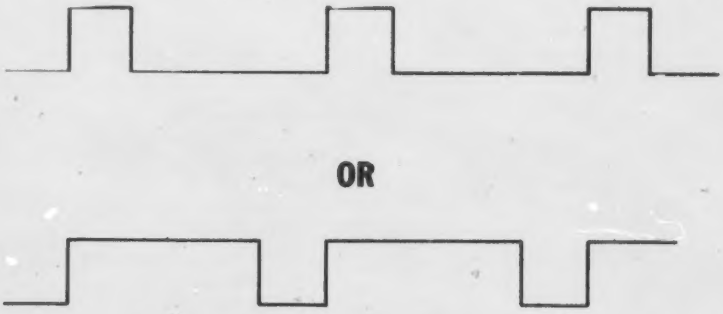


Figure 7

To do this, you would need to change the time the transistor is cut-off. Well, how about changing the RC time constants? Look at Figure 8.

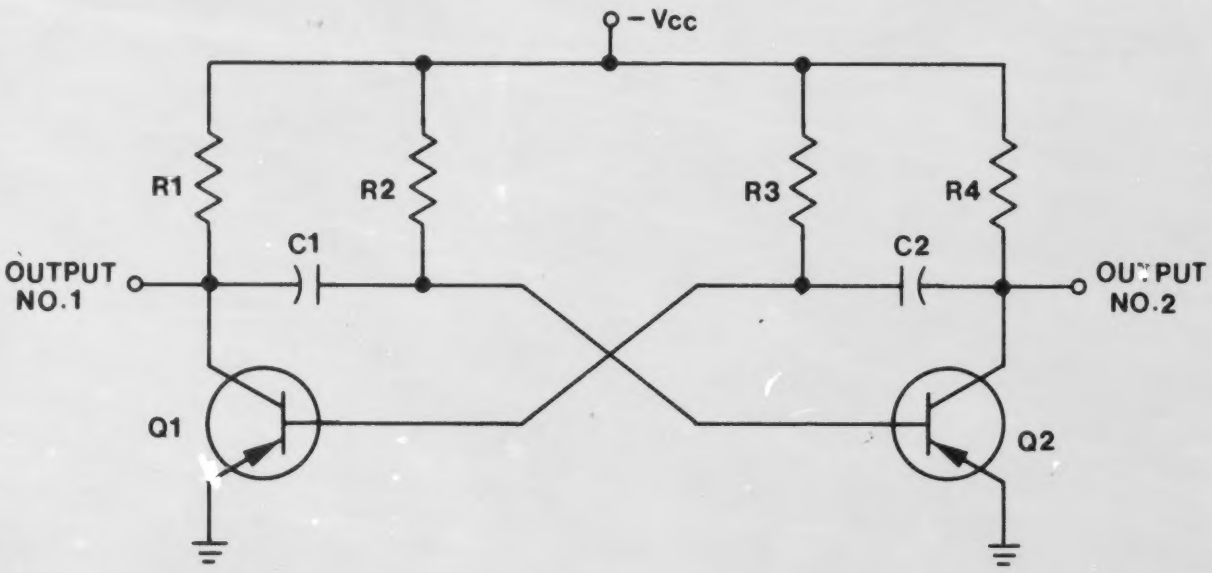


Figure 8

The time Q2 is in a cut-off state will be determined by the Time Constant of $R_2 \times C_1$. When $R_2 \times C_1$ reaches a predetermined value the base of Q2 becomes sufficiently negative enough to cause it to go into conduction.

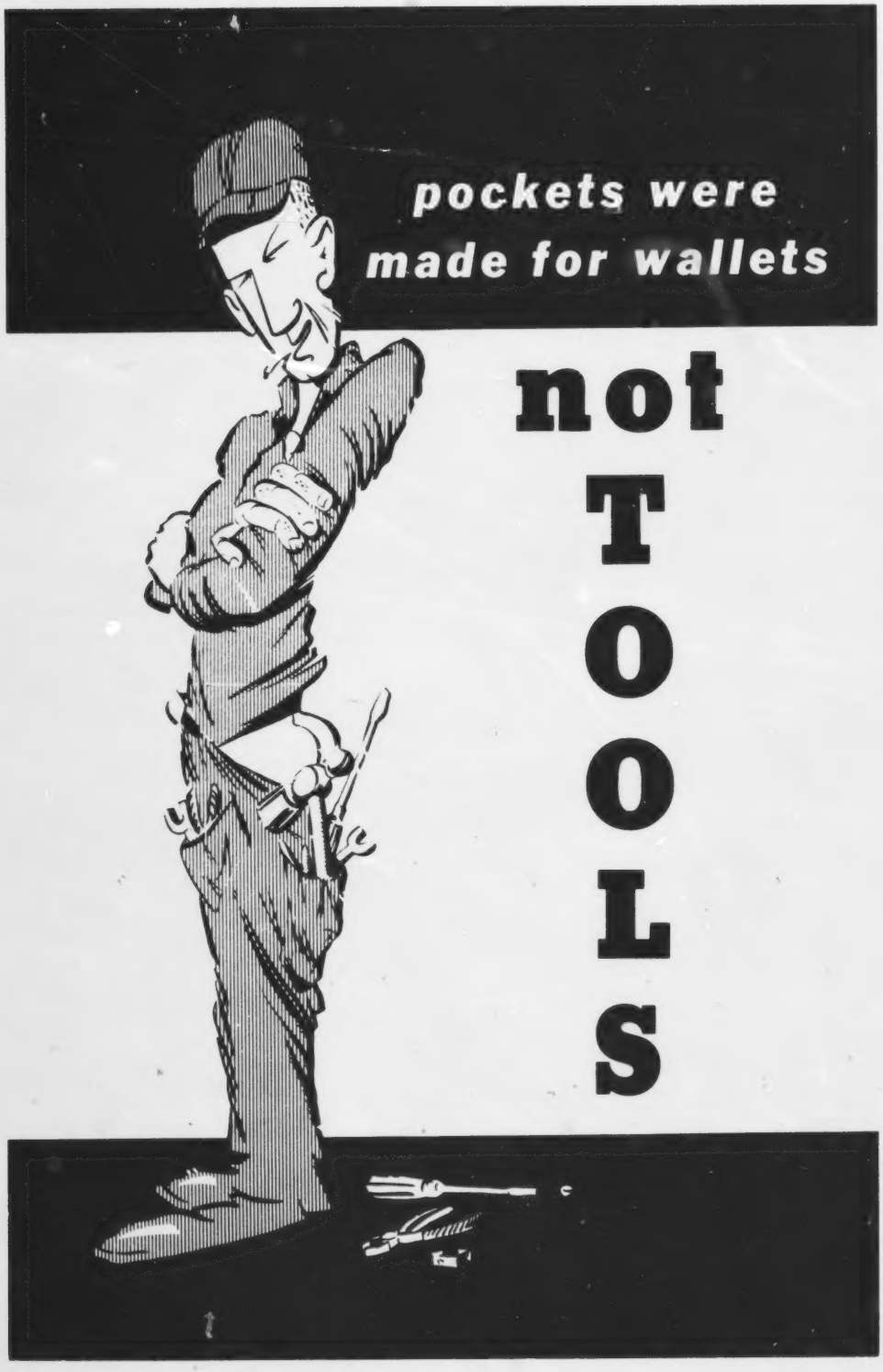
When Q2 goes into conduction, C2 will begin to charge. Once C2 reaches a predetermined value, it will cause Q1 to go into conduction and cause Q2 to cut-off once again. Q1's cut-off time will be controlled by the time constant of $R_3 \times C_2$.

So what good is it? Well, the astable multivibrator is used in many applications that require triggering at a particular frequency. In a sense, it's an electronic clock -- ticking and tocking at a steady rate.

The astable multivibrator is used for

a. amplification.
b. timing.
c. regulation.
d. differentiating.

- -


pockets were
made for wallets
not
TOOLS

b. timing.

7. TEST FRAME

(1) The astable (free-running) multivibrator has

a. two inputs, two outputs.
b. one input, one output.
c. one input, two outputs.
d. no inputs, two outputs.

(2) The output of an astable multivibrator is a

a. negative DC voltage.
b. a square wave.
c. a sine wave.
d. positive DC voltage.

- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

(1) d. No inputs, two outputs.
(2) b. A square wave.

IF YOUR ANSWERS ARE INCORRECT, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON II

Astable Multivibrator Operation (Free-running)

An astable multivibrator is also known as a free-running multivibrator. We call it free-running because it freely alternates between two different output voltage levels all the time it is on. The output remains at each voltage level for a definite period of time. If you looked at this output on an oscilloscope, you would see the below waveform:

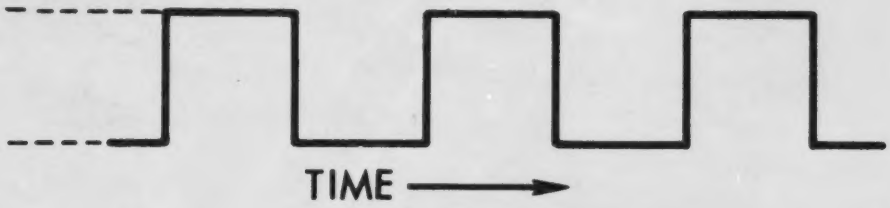


Figure 1

Remember what this kind of waveform is called? It is a square-wave. The astable multivibrator operates like a square-wave oscillator.

Why do we say it is like an oscillator? Well, an oscillator is a circuit that generates a continuous output waveform with no input signal. The astable multivibrator has no input. You should recall that the bistable multivibrator (flip-flop) has two inputs and two outputs. The astable multivibrator also has two outputs, but no inputs.

The schematics for the two multivibrators appear similar. Take a look at the astable multivibrator schematic in Figure 2.

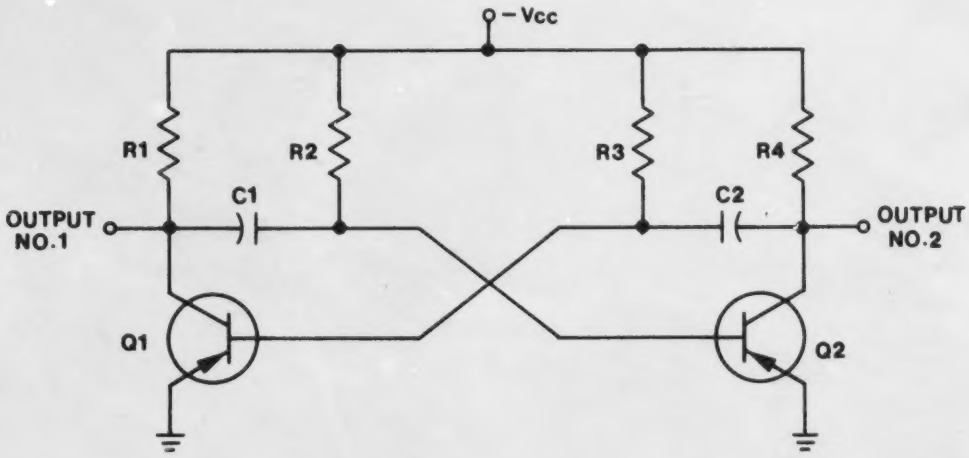


Figure 2

In addition to appearance, there are other similarities between the astable and bistable multivibrators. Like the flip-flop, one of the transistors will saturate and the other transistor will cut-off when we energize the circuit. Therefore, one output will be a relatively high voltage (approximately -Vcc) when the other output is a low voltage (approximately 0 V).

But the astable multivibrator "oscillates," whereas the flip-flop doesn't. In order to explain why the astable multivibrator oscillates, let's assume that transistor Q1 saturates and transistor Q2 cuts off when we energize the circuit. This situation is shown in Figure 3.

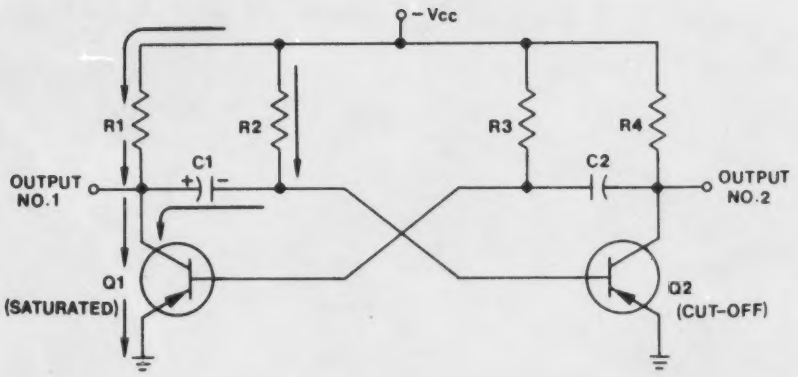


Figure 3

Essentially ALL the current in the circuit flows through Q1. Q1 offers almost no resistance to current.

Notice that capacitor C1 is charging. Since Q1 has almost no resistance in a saturated state, the rate of charge of C1 is dependent on which time constant?

a. R1 X C1
b. R2 X C1
c. R3 X C1

- -

b. R2 X C1

Let's take another look at Figure 3. Notice that the right-hand side of capacitor C1 is connected to the base of transistor Q2. Q2 is now cut-off.

Let's put one and one together. First one: the right-hand side of capacitor C1 is becoming more and more negative. Second one: if the base of Q2 becomes sufficiently negative, Q2 will conduct. Conclusion: after a certain period of time, the base of Q2 will become sufficiently negative to cause Q2 to change from cut-off to conduction. What do you suppose determines how long it takes for Q2 to become saturated? "The time constant," you say. What time constant? "R2 X C1."

So what happens now? Look at Figure 4.

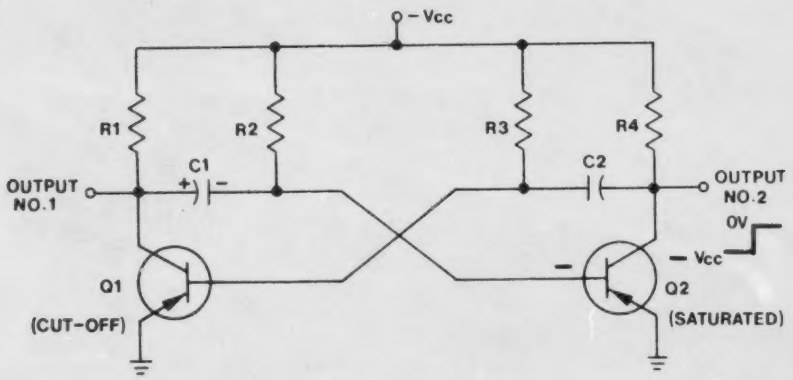


Figure 4

The negative voltage on the right side of capacitor C1 has caused Q2 to conduct. Now the following sequence of events will take place almost instantaneously. Q2 starts conducting and quickly saturates, and the voltage at output #2 changes from approximately -Vcc to approximately 0.0v. This change in voltage will be coupled through C2 to the base of Q1, causing Q1 to cut-off.

Now we have Q1 in cut-off and Q2 in saturation. See Figure 5.

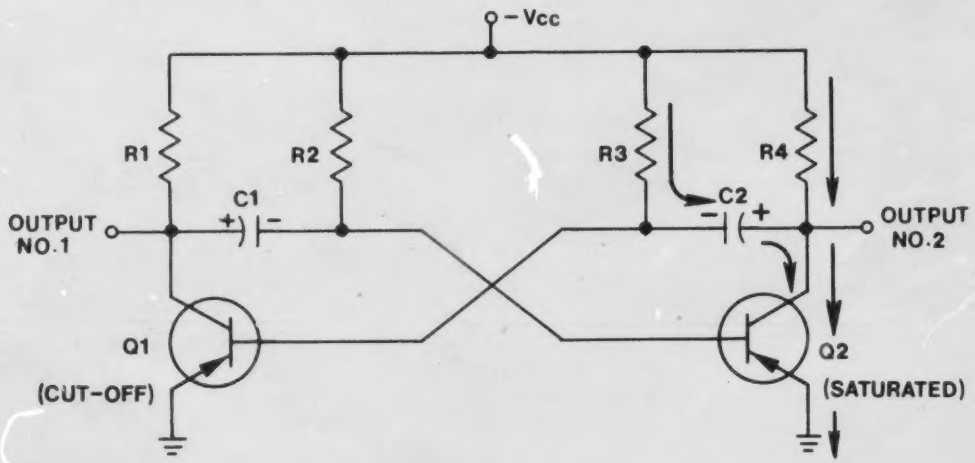


Figure 5

Notice that Figure 5 is the mirror image of Figure 3. The left side of capacitor C2 will now become more negative at a rate determined by the time constant R3 X C2. As the left side of C2 becomes more negative, the base of Q1 will also become more negative. When the base of Q1 becomes negative enough to allow Q1 to conduct, Q1 will again go into saturation. The resulting change in voltage at output #1 will cause Q2 to go back to cut-off.

The length of time that transistor Q1 remains cut-off is determined by the charging rate of capacitor _____.

- -

C2

Let's take a look at the output voltage from transistor Q2. Figure 6 illustrates the waveform at the output of Q2.

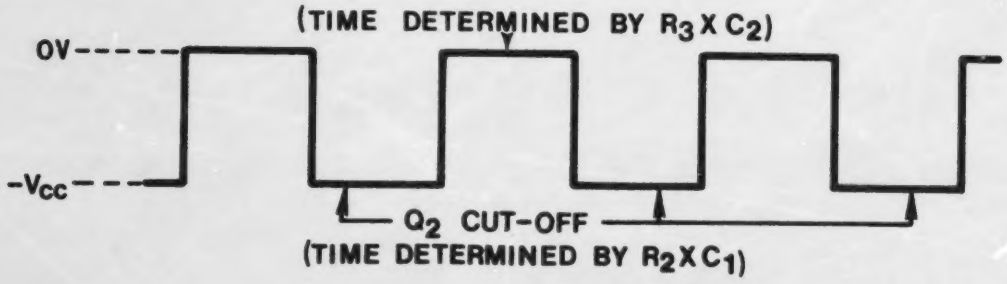


Figure 6

The output voltage (from either output) continually alternates from approximately 0.0v to approximately -Vcc -- remaining in each state for a definite period of time. The time may range from a microsecond to as much as a second or two. In many applications, the time period of high voltage (-Vcc) and the time period of low voltage (0.0v) will be equal.

Some applications, however, require different high and low voltage times. Timing circuits and gating circuits often have different pulse widths. (Figure 7.)

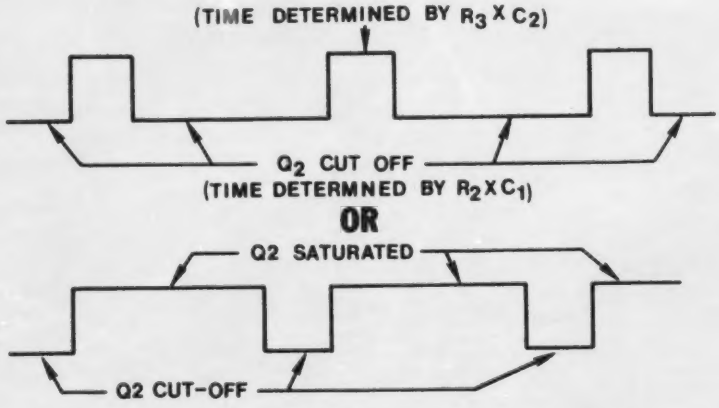


Figure 7

To increase the length of time a transistor is saturated or cutoff, one of the RC time constants [(R_3 X C_2) or (R_2 X C_1)] must be increased.

The astable multivibrator is basically used as a timing circuit or a gating circuit. Sometimes it is called an electronic clock -- ticking and tocking at a steady rate.

The output of an astable multivibrator is

a. negative DC voltage.
b. a square wave.
c. a sine wave.
d. positive DC voltage.

- -

b. a square wave

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY THREE

LESSON III

MONOSTABLE MULTIVIBRATOR OPERATION (ONE-SHOT)

1 APRIL 1977

OVERVIEW
LESSON III

Monostable Multivibrator Operation (One-Shot)

In this lesson, you will study and learn about the schematic, function, the input and output waveforms of a monostable multivibrator.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

23.3.45 When the student completes this course, he will be able to TROUBLESHOOT multivibrator (flip-flop, free-running, one-shot) circuits, given a prefaulted training device, appropriate schematics (or technical manual), test equipment, and necessary tools. Remove and replace similar components on a practice circuit board. Faulty component identification must be 100% accurate. Component replacement must pass Learning Supervisor's inspection.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

23.3.45.7 IDENTIFY the schematic diagram of a one-shot (monostable) multivibrator by selecting the correct schematic from a set of four choices. 100% accuracy is required.

23.3.45.8 IDENTIFY the correct output waveform of a basic one-shot (monostable) multivibrator by selecting the correct one-shot multivibrator output, for a given input, from a set of four choices. 100% accuracy is required.

OVERVIEW

23.3.45.9 CONSTRUCT a basic one-shot (monostable) multivibrator, given a schematic diagram or a parts layout template and a supply of parts. The constructed circuit must be operational as specified in the job program.

23.3.45.9.1 OBSERVE, RECORD, and INTERPRET normal and abnormal output waveforms of a one-shot (monostable) multivibrator, given the necessary schematics, tools, job program, an oscilloscope, and components or circuit boards. All measurements must fall within tolerances stated in the job program.

23.3.45.10 IDENTIFY a malfunctioning component in a prefaulted multivibrator (Bistable, Astable, Monostable) circuit, given the necessary tools, job program, a prefaulted training device, an oscilloscope, and the appropriate technical manual or schematic. Fault diagnosis to be 100% correct.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON III

Monostable Multivibrator Operation (One-Shot)

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following study resources:

Written Lesson presentation in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Job Program Twenty Three-III-1 "Monostable Multivibrator"
Job Program Twenty Three-III-2 "Multivibrator Systems"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Three-III "Monostable Multivibrator Operation"

Enrichment Material(s):

Basic Electronics, Vol. 2, NAVPERS 10087-C

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

SUMMARY
LESSON III

Monostable Multivibrator Operation (One-Shot)

The monostable multivibrator circuit is basically used for pulse-shaping. Frequently it is known as a one-shot multivibrator. It is used in computer logic systems, electronic control systems, radar pulse-forming systems, and communication/navigation equipment. The one-shot will take a series of input trigger pulses and convert them to uniform square pulses (Figure 1).

Figure 1

A schematic for a monostable multivibrator is shown in Figure 2.

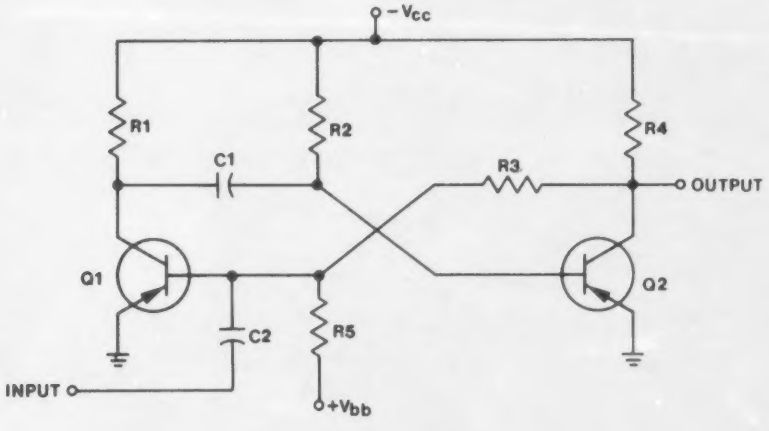


Figure 2

Immediately after the one-shot is energized, transistor Q1 will cut-off and transistor Q2 will saturate. Notice that a positive voltage ($+V_{bb}$) is applied to the base of Q1 through R5. Q2 will saturate because of the negative voltage applied to its base through R2. The circuit is now in its stable state (monostable means one stable state), as shown in Figure 3.

The output of the one-shot is taken from the collector of Q2. Since Q2 is saturated, the output voltage is approximately 0 V (Figure 3).

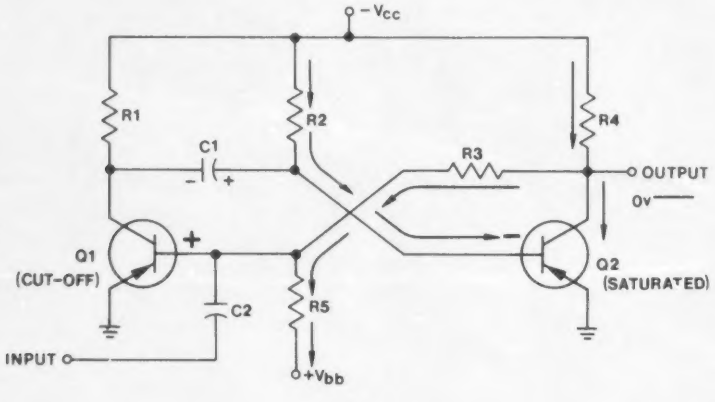


Figure 3

As long as you do not apply an input signal, the output will continuously measure zero volts.

If you apply a negative pulse at the input of the one-shot circuit in Figure 4, the base of Q1 will become negative. Q1 will immediately saturate -- causing the voltage at its collector to rise to approximately zero volts. This rise in voltage is coupled through C1 to the base of Q2 -- causing Q2 to cut-off. When Q2 stops conducting, the voltage at its collector drops to approximately $-V_{cc}$.

The output voltage is now $-V_{cc}$. The output voltage will now remain at $-V_{cc}$ for a definite period of time determined by the time constant R2 x C1. In other words, as the right side of C1 becomes more and more negative, the base of Q2 will become more and more negative.

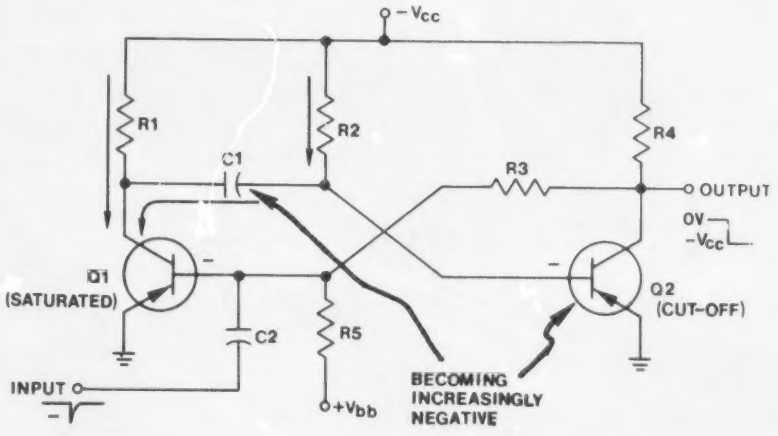


Figure 4

Eventually, the base of Q2 will become sufficiently negative to cause Q2 to conduct. Q2 will rapidly saturate, and the output voltage will rise to 0 V. The circuit has then returned to its stable state (Figure 5).

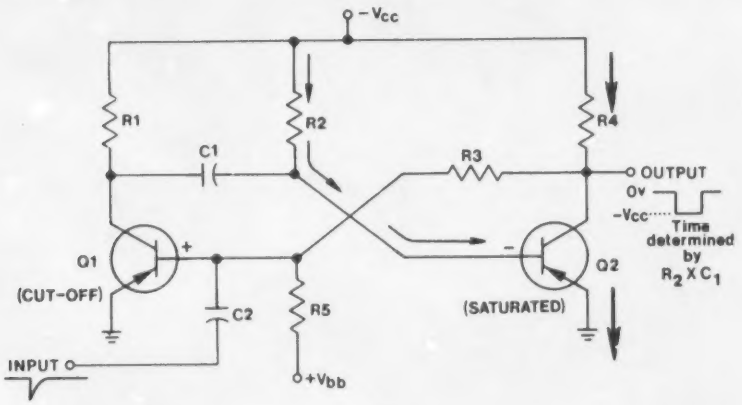


Figure 5

Each time a negative pulse is applied to the input, the one-shot output will change from 0 V to $-V_{cc}$. It will remain at $-V_{cc}$ for a definite length of time. Then it will automatically return to 0 V.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON III

Monostable Multivibrator Operation (One-Shot)

TEST FRAME IS 11. AS BEFORE, GO FIRST TO TEST FRAME 11 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. There are numerous applications of the monostable multivibrator. You will discover that it is a very versatile circuit. It is used in computer logic systems, electronic control systems, radar pulse-forming systems, and communication/navigation equipment. Each of these systems requires a circuit that takes a series of input trigger pulses and converts them to uniform square pulses. All the square output pulses will be the same amplitude and time duration. See Figure 1.

Figure 1

The monostable multivibrator could best be classified as a/an:

a. amplifier circuit.
b. pulse-shaping circuit.
c. oscillator circuit.
d. filter circuit.

- -

b. pulse-shaping circuit.

2. The schematic for the monostable multivibrator (also known as the one-shot) is shown in Figure 2.

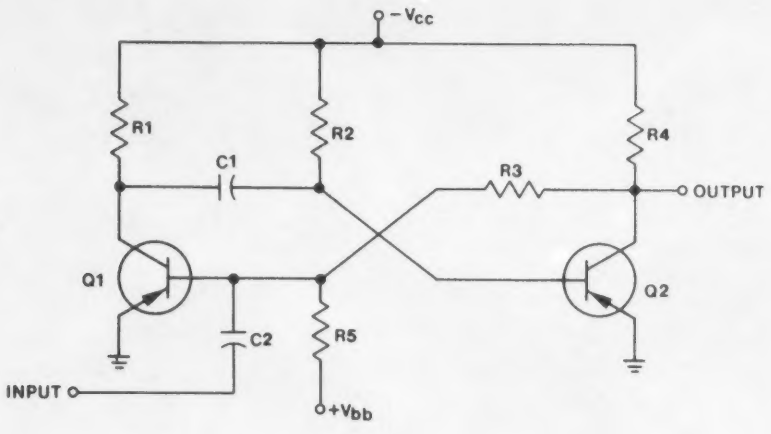


Figure 2

The one-shot circuit has only one input (recall that the astable multivibrator has no inputs and the bistable multivibrator has two inputs). There is generally only one output -- taken from the collector of Q2. A second output could be taken from the collector of Q1. This second output would be the exact reverse of the first.

The monostable multivibrator has _____ input(s).

- -

one

76

3. The previous two multivibrators (astable and bistable) were symmetrical. The monostable is not symmetrical. Notice that the two transistors in the monostable multivibrator (Figure 3) are biased differently.

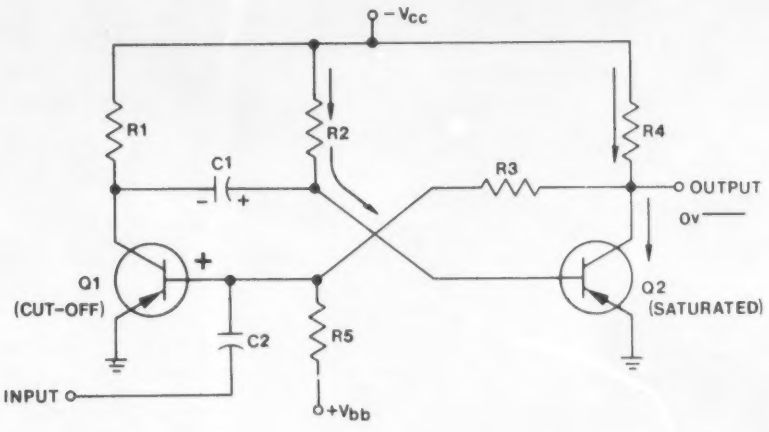


Figure 3

When the circuit is first energized, a positive voltage is applied to the base of Q1 through the voltage divider action of R5, R3 and R4, while a negative voltage is applied through R2 to the base of Q2. As a result, Q1 is cut off and Q2 saturates. The circuit will remain in this state indefinitely; it will not change unless some external force affects it. This is the reason for the circuit's name; it has only one stable state (monostable).

In its static state, Q1 in the monostable multivibrator (Figure 3) will be (cut off/saturated) and Q2 will be (cutoff/saturated).

- -

cut off, saturated (in that order)

4. Let's take a closer look at what this circuit is doing in its stable state. With Q2 saturated, its collector voltage is -0.5 V (R4 dropping most of V_{cc}) so R3 and R5 act as a voltage divider between V_{bb} and ground. The potential at the tie point between R5 and R3 is somewhere between 0 volts and +6V, thus the voltage on the base of Q1 must be positive and, as we said earlier, Q1 is held at cut off. With Q1 cut off, its collector voltage is at -12V, for without current flow through R1, there is no voltage drop across R1. R2 is dropping nearly all of V_{cc}, because one end is connected to V_{cc} and the other end to negative 0.3 volts at the base of Q2. C1, with one end connected to -12V at Q1's collector, is charged to approximately 12 volts with the left end most negative.

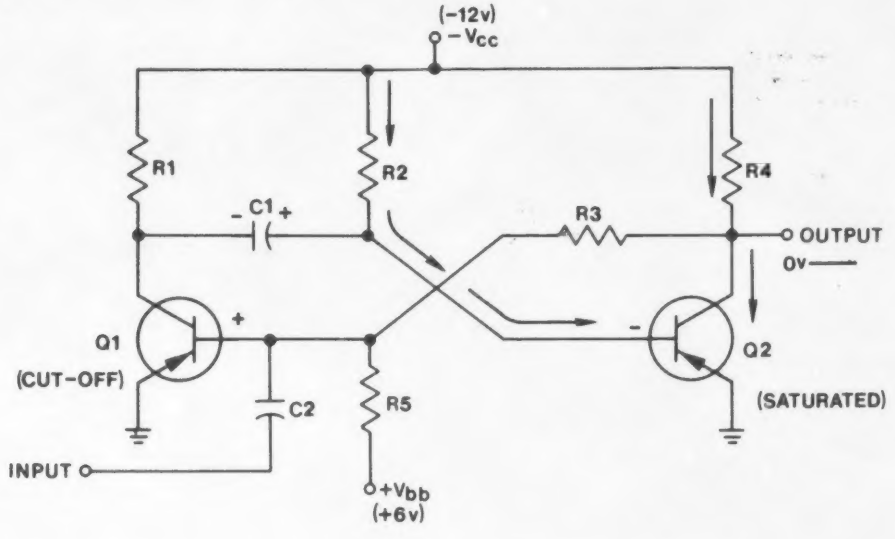


Figure 4

Basically, this circuit will not change states because _____ is connected to a positive voltage.

- -

Q1's base

5. Now let's get to that "external force" that can change the state of this multivibrator. A negative trigger pulse of about one volt (or more) at the input will cause Q1 to conduct, and Q1's collector voltage will instantly change to nearly zero volts. The charge on C1 now will act as a voltage source with its left side at ground potential and a positive voltage on its right base terminal. This positive voltage will cut off Q2; Q2's collector will promptly go to -12V; and the R3-R5 voltage divider will hold the base of Q1 to about -0.3V to lock Q1 in saturation.

When an input pulse cuts off Q1, the sudden change in its collector voltage is coupled to Q2 by _____.

- -

C1

6. Once again, let's go over the circuit in detail, this time looking at conditions as they are just after a negative input pulse has been applied. Q1 is saturated; it's collector has a very small voltage; and R1 drops approximately 12 volts. C1 is charged to nearly 12 volts, so the base of Q2 is about 11 volts positive -- more than enough to positively cut off Q2. With Q2 cut off R3, R4 and R5 act as a voltage divider network between -12 V (V_{cc}) and +6V (V_{bb}). The circuit values are chosen so that this holds Q1's base at about -3V which keeps Q1 conducting.

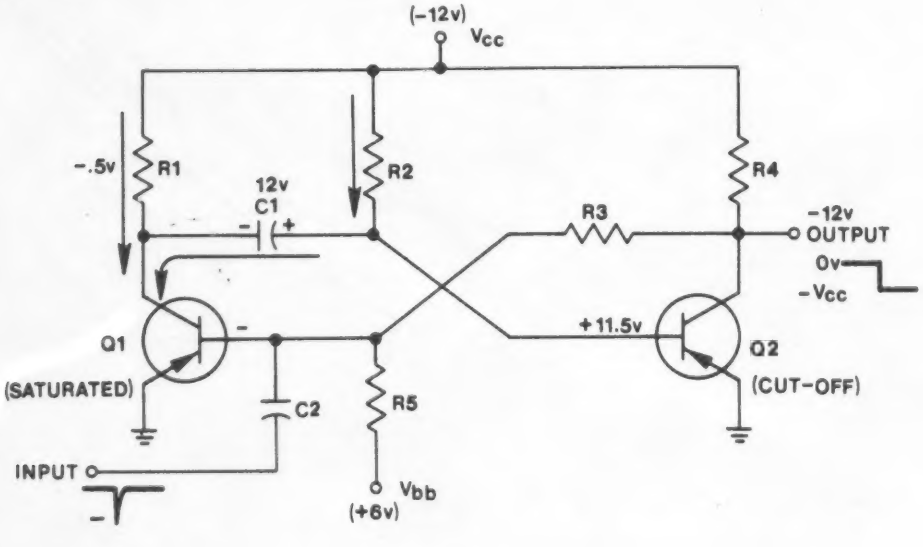


Figure 5

What component causes the base of Q2 to be positive?

- -

C1

7. The circuit is now in an unstable condition. It will remain in this state for a definite period of time. It will then revert automatically back to its original stable state.

In Figure 6, electrons flowing through R2 to the right side of C1 will balance the charge on C1 (discharge C1) so that the base of Q2 gradually becomes more negative. At some point, Q2 will start conducting again; this will cause Q1 to cut off and the circuit will flop back to its stable state. The length of time that Q2 is cut off depends on the RC time constant of C1 and R2. (You may want to review RC time constants at this time.)

What will happen to Q2's cut off time if the value of R2 increases?

- -

Q2 will be cut off longer

8. Let's use a timing diagram to quickly go through this operation again. (A timing diagram is a series of wave forms taken from different points in a circuit and drawn on the same time base to show time relationship.)

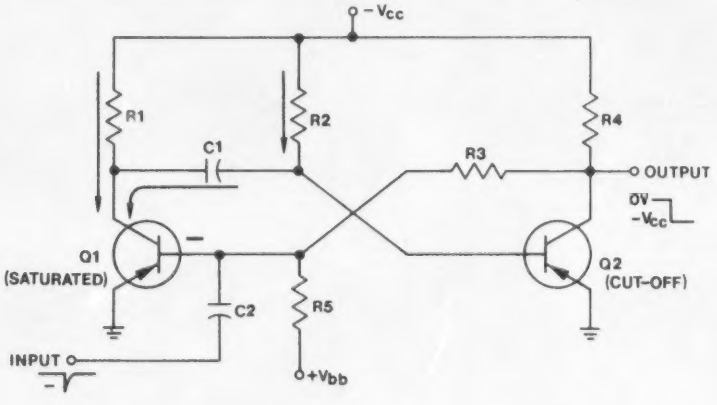


Figure 6

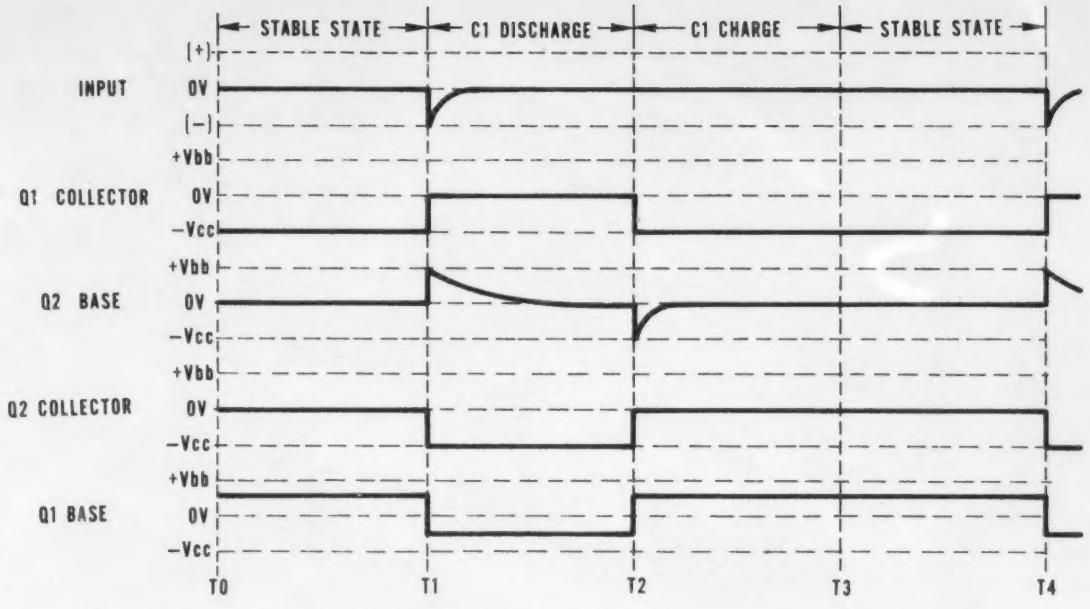


Figure 7

At time zero (T_0) the circuit is in its stable state and all the voltages are just sitting there, nice and steady -- until T_1. T_1 is when we apply an input pulse and a lot of things start happening; Q1's collector goes positive to about zero volts, C1 couples the positive charge to the base of Q2. Q2 cuts off and causes its collector voltage to drop to -12V, and this causes the base of Q1 to drop to a negative value (saturate). Remember, all this happens so fast that we can't see any time difference in these events.

Now, during the time from T_1 to T_2, C1 is discharged by the current through R2, and their time constant determines how long it is from T_1 to T_2. All this time the collector of Q1 is at zero volts, the collector of Q2 is negative, and Q1's base is negative.

At T_2, the base of Q2 finally becomes negative enough to cause Q2 to conduct. The other voltage changes shown on the diagram take place instantaneously and the circuit returns to its stable state -- except for the peak at the base of Q2. You've probably already quessed that this peak is caused by C1's charging back up to twelve volts. This charge time is much shorter for the charge path is through R1 now, and R1 has much less resistance than R2. As soon as C1 has completely charged, the multivibrator reverts to its stable state and will just sit and wait for the next input pulse to come along.

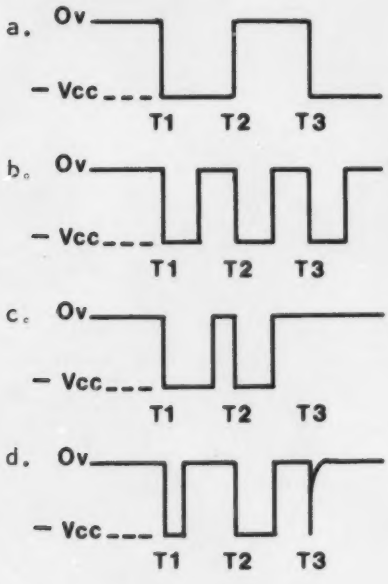
What determines the length of time that the collector ar Q2 remains negative?

- -

The time constant of C1 and R2.

9. The normal output from the one shot multivibrator is taken from the collector of Q2, so the output is a fixed width, negative pulse for each input pulse. If, for some reason, we want a positive going pulse, we can use a circuit containing NPN transistors or we can take the output from the collector of Q1 in a PNP transistor circuit. (See Figure 6 in Frame 8.)

Select the correct output waveform given the below input waveform to a one-shot multivibrator which uses PNP transistors.

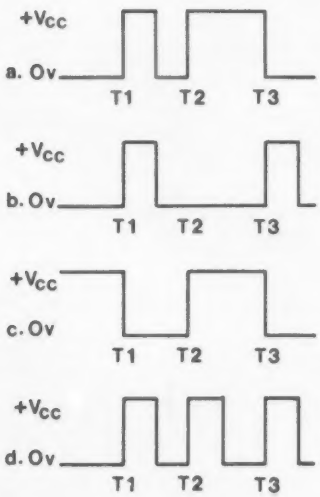


- -

b.

10. The input trigger pulses and the output square pulses may be either positive or negative depending on the type of transistors used in the one-shot. The circuit discussed up to this point used PNP transistors. The inputs and outputs were negative.

Say that the below one-shot circuit used NPN transistors. Select the correct output waveform.



- - - -

LEAVE ELECTRICAL WORK TO ... ELECTRICIANS

reminder...

Average man is a 0.25- megohm,
1- watt resistor.
at 1 milliampere, shock is perceptible-
...at 10 mils you can't let go-
... 100 mils is generally fatal-
...and technicians
are already in short supply.

[illegible]

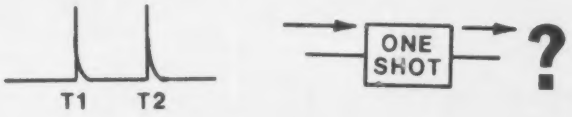
Prepared by
Naval Safety Center
Naval Air Station
Norfolk, Virginia 23511

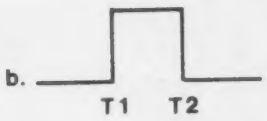
11. TEST FRAME

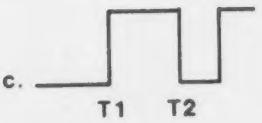
1. The basic function of a monostable multivibrator is:

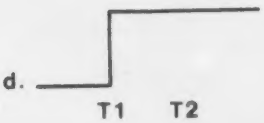
   a. filtering.
   b. pulse-shaping.
   c. amplification.
   d. differentiating.

2. Select the correct output waveform given the below input waveform to a one-shot multivibrator which uses NPN transistors.









- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

1. b. pulse shaping

2. a.

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON III MODULE TWENTY THREE. OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME II AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON III

Monostable Multivibrator Operation (One-shot)

The operation of the monostable multivibrator (one-shot) is relatively simple. You trigger the input with a pulse of voltage. The output changes from one voltage level to a different voltage level. The output remains at this new voltage level for a definite period of time. Then the circuit reverts automatically to its original condition -- remaining that way until another trigger pulse is applied to the input.

The schematic for the one-shot (another name for the mono-stable multivibrator) is shown in Figure 1.

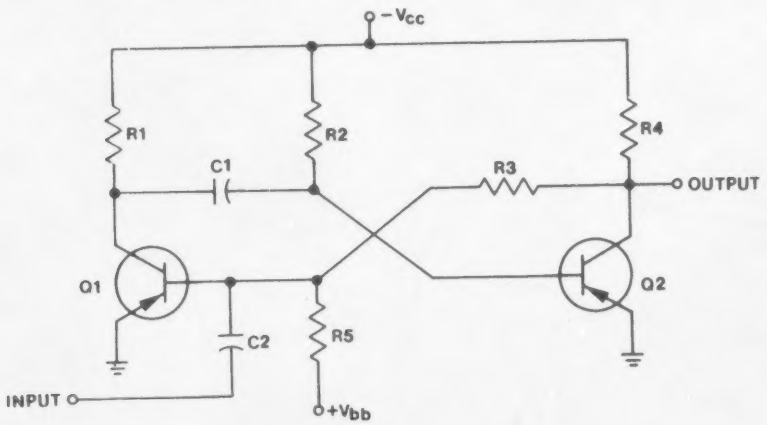


Figure 1

Like the other multivibrators, one transistor will saturate and the other transistor will cut off when we energize the circuit.

After you first energized the other two multivibrators, it was impossible to predict which transistor would initially go to cut-off. But the one-shot circuit is not symmetrical like the flip-flop and the astable multivibrators. Positive voltage (+Vbb) is applied through R5 to the base of Q1. This positive voltage will cause Q1 to cut-off. Transistor Q2 will saturate because of the negative voltage applied from -Vcc to its base through R2.

Therefore, Q1 will be cut-off and Q2 will be saturated before we apply a trigger pulse.

The output of the one-shot is connected to the collector of Q2. Since Q2 is saturated, the output voltage is approximately 0.0V. (Figure 2.)

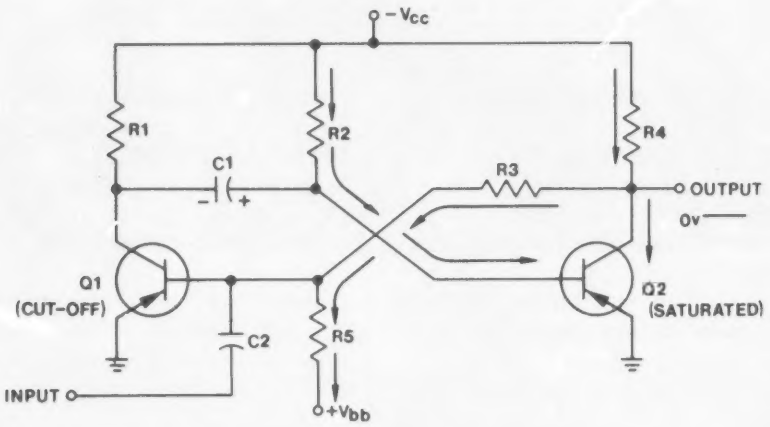


Figure 2

The circuit is now in its stable state. The monostable multivibrator has one stable state (mono means one; monostable means one stable state). As long as you do not apply an input signal, the output will continuously measure zero volts.

Let's take a more detailed look at the circuit conditions in this stable state (refer to Figure 2). As we said Q1 is cut off, so there is no current flow through R1 and the collector of Q1 is at -Vcc. Q2 is saturated and has practically no voltage drop across it, so its collector is at essentially zero volts. R5 and R3 form a voltage divider from +Vbb to the ground potential at Q2's collector. The tie point between these two resistors must therefore be positive. Thus the base of Q1 is held positive ensuring that Q1 remains cut-off. Q2 will remain saturated because the base of Q2 is very slightly (probably about 0.5V) negative, for it is returned to -Vcc and Q2's condition will keep its base potential near its emitter potential by the voltage drop across R2. Now, if the collector of Q1 is near -Vcc and the base of Q2 is near ground; C1 must be charged to nearly Vcc volts with the polarity shown in Figure 2.

OK, now that we have all the components and voltages sorted out for the stable state -- let's see how it operates. This is done by applying a negative pulse at the input terminal. C2 couples this voltage change to the base of Q1 and starts Q1 conducting. Q1 will quickly saturate, and its collector voltage will immediately rise to ground potential. This sharp voltage rise will be coupled through C1 to the base of Q2 -- causing Q2 to cut-off. Q2's collector voltage immediately drops to Vcc; the voltage divider formed by R5 and R3 will then hold Q1's base negative (it's designed that way), and Q1 is locked in saturation. This is shown in Figure 3.

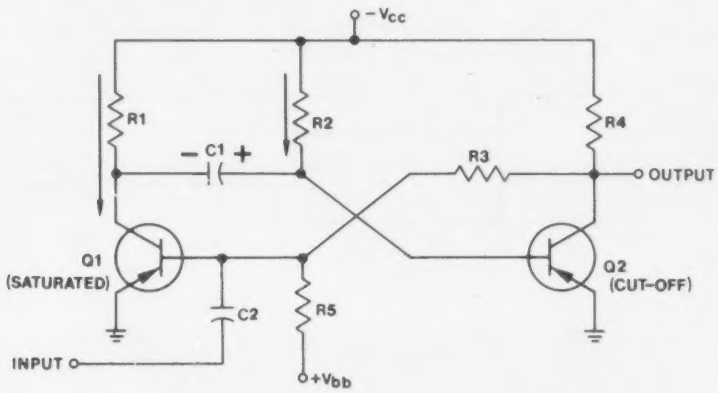


Figure 3

We have now turned the one-shot "on" by applying a pulse at the input. It should turn itself "off" after a period of time. Let's see if it does.

Looking at Figure 3, we know Q1 is held in saturation by a negative voltage connected through R3 to its base, so the circuit can't be turned off here. Let's look at the base of Q2. This base is connected to the negative supply (-Vcc) through R2, so the base is negative and Q2 is conducting, right? Wrong! We just coupled a positive voltage change (pulse) from Q1's collector to the base of Q2 and cut Q2 off. Maybe we need to take a closer look at what is happening here! When the collector of Q1 switches from -Vcc volts to zero volts, the charge on C1 acts like a battery with its negative terminal on Q1's collector and its positive terminal connected to Q2's base, and this voltage is what cuts Q2 off. But R2 connects the positively charged plate of C1 to a negative source, so C1 must begin to discharge through Q1 to ground, back through -VCC, through R2 and the other side of C1. How long will it take for C1 to discharge? That depends on the RC time constant of C1 and R2. (You may want to review RC Time Constants.) A timing diagram (Figure 4) shows these events in a way that should be fairly clear now. Go back through the description following the events in these waveforms if you aren't sure you understand what is happening.

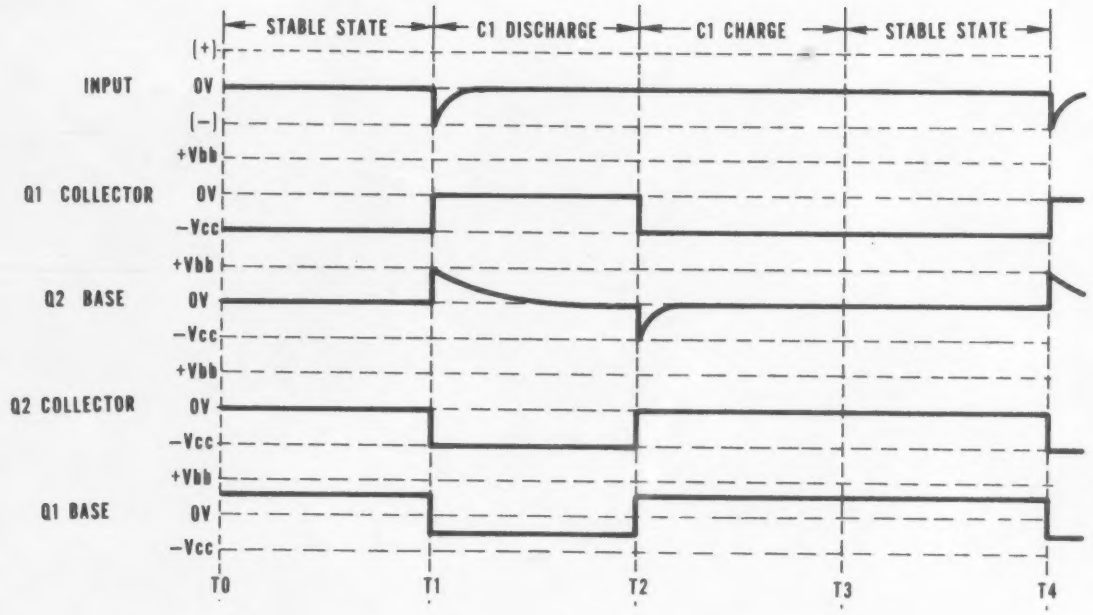


Figure 4

The only part of the operation not described so far is the short C1 charge time that occurs right after Q1 and Q2 return to their stable states. This is simply the time required for C1 to gain electrons on its left side, and it is determined by the R1 X C1 time constant.

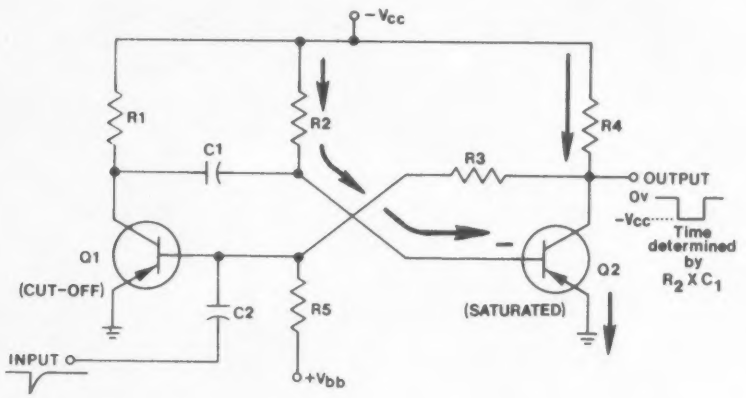


Figure 5

The length of time that the output remained at -Vcc was determined by the time constant R2 x C1.

Now the output will remain at 0 volts until another pulse is applied at the input.

By now, you are probably wondering "What good is it?" Well, the one-shot multivibrator is a very useful circuit. Basically, it is used as a pulse-shaping circuit. A series of trigger pulses at the input will produce a series of uniform square pulses at the output. See Figure 6.

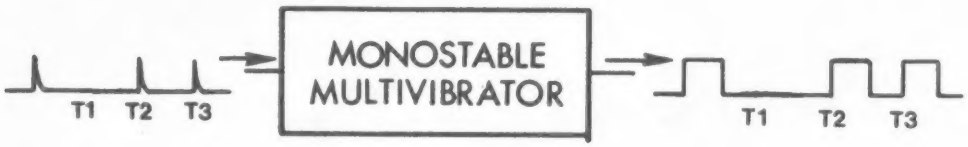
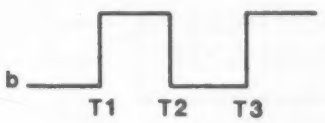
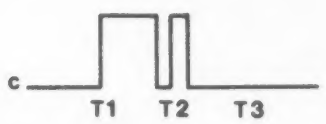


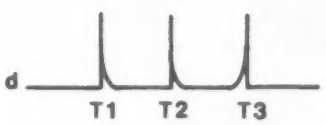
Figure 6

Applications include computer logic circuits, electronic control circuits, radar pulse-forming circuits, and communication/navigation equipment. As you continue your study of electronics, you will encounter various applications of the one-shot as part of more complex circuits. Like the other multivibrators, it is a building block that performs one function in a larger structure.

Given the below input waveform to a one-shot multivibrator, select the correct output waveform.







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